MEDULLARY NAILING
OF KUNTSCHER

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First English Edition
revised by the author

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TRANSLATOR'S PREFACE

This book was originally published in German as the third volume of Böhler's comprehensive work on fractures, and it deals exclusively with medullary nailing. Because of the widespread interest and urgent demands for an authoritative and detailed presentation in the English language of this new method, it was decided to publish a translation of this third volume as an independent book. The references to the other two volumes of Böhler's work have been retained in this book, since a translation of these two volumes revised by Dr. Böhler is now in preparation. The extraordinary demand for an early publication on medullary nailing did not permit of delay by an attempt to first translate and publish the first two volumes.

Küntscher's medullary nailing represents a new milestone in the treatment of fractures. Like previous daring innovations, it will undergo transition periods of now skeptic and now enthusiastic reception, of widespread use, partly indiscriminate and improper, of amazing results and disappointing failures—but eventually it seems certain to be added gratefully by many to their armamentaria, as a precious and potent addition for the treatment of selected cases.

For a critical evaluation of the merits and inherent dangers of any new method, extensive experience with other procedures is a prerequisite. Dr. Böhler who has treated tens of thousands of fracture cases during the last decades by his own and other methods and had an opportunity to re-examine the vast majority of these up to thirty years later is uniquely and preëminently suited for this service to the profession. He has set forth his experiences in this book and generously illustrated the the reasons for his conclusions and advice. It should obviously be heeded.

It may seem odd that Dr. Böhler has here incorporated detailed descriptions of procedure even in cases where he does not recommend medullary nailing at present. But there is ample reason for this. No one can say what rôle bacteriostatic drugs and antibiotics may play in the future development of the procedure, should the hoped for development eventuate these detailed descriptions will be most welcome.

This is not only a textbook but even more a manual to which one who plans to use this method will frequently refer for practical aid in the face of clinical requirement. He will then appreciate the repetition of all important details in each chapter.

In the translation I have endeavored faithfully to convey Dr. Böhler's emphasis and meticulous attention to details in his plain and indoctrinating style in easily readable and clearly understandable language, choosing English equivalents for new German medical terms only after careful deliberation. The conversion tables in the back of this book will probably be found helpful by many readers.

Abroad, disappointing experiences with medullary nailing have occurred due entirely to lack of full information concerning correct indications, contra-indications and technique. It is my hope that this book appears early enough to prevent a repetition of such experiences in the English speaking world, and that it will contribute to the furtherance of a proper use of an exceedingly effective method.

HANS TRETTER, M.D.

PREFACE TO THE FIRST ENGLISH EDITION*

Küntscher's medullary nailing is an astonishing and important innovation in traumatic surgery With careful selection of cases and proper technique it is superior to all previous methods for the treatment of fresh closed fractures, especially those of the femur Compared with our previous experiences, it is amazing to see a man with so serious an injury as a femoral fracture walk painlessly two weeks later with neither cast nor brace and with freely movable joints

This is possible because this form of osteosynthesis provides real stability, exactly like that afforded by the three flanged nail of Smith Peterson and Sven Johansson

In order to obtain a comprehensive survey of the indications, technique and final results, I have studied the literature to date as well as the case histories of more than 600 injured who were treated with the medullary nail Of these, 268 were cared for at our Accident Hospital in Vienna, the rest were patients at other institutions or were seen in consultation I have reviewed a total of over 12,000 X ray pictures several times from various standpoints

This study of the literature and of the 600 case histories as well as many verbal reports revealed not only good results but an unbelievably large number of complications and failures besides a considerable number of fatalities These complications arose from the fact that many physicians, in their first enthusiasm, believed that medullary nailing may be performed without due regard for the general condition and age of the injured or for the fundamental principles of fracture treatment and of traumatic surgery

The dangers of any osteosynthesis are infection metal-corrosion damage and delayed callus formation To these must be added complications arising from incorrect indication and defective technique

With closed medullary nailing infections are very rare They were observed more often with open nailing Under scrupulous asepsis and with the use of penicillin they can probably be reduced to a minimum

Metal damage was quite frequently noted With the use of V 2 A steel and especially of Vitallium this complication can be largely eliminated Küntscher's statements concerning the callus stimulating effect of the medullary nail had made the greatest impression upon me because none of the many measures heretofore advocated for this purpose has proven of value Unfortunately I found that the medullary nail like any other foreign body, does not stimulate, but inhibits the formation of callus and that its presence may, with faulty technique, even lead to pseudarthrosis However since this form of osteosynthesis is very stable if the indication and technique have been correct, especially on the femur and since a patient treated with a nail may walk before the bone itself has united the delay in the production of callus is of negligible significance Medullary nailing has greatly stimulated the study of callus formation and I have therefore devoted a large amount of

* Incorporates the substance of the prefaces to the 1st–11th German editions 1944–1945

space to this subject Fatalities were observed chiefly in femoral fractures and were due mainly to faulty indication and to operation during shock.

Most failures were due to defective technique Medullary nailing was originally represented as a simple procedure Frequently, however, it is quite difficult I have therefore endeavored to describe it in minute detail

On the basis of previous experience I have attempted to sharply define the indications in order that proper advice may reduce to a minimum the number of fatalities serious infections and other complications. For fresh compound fractures of the lower leg and of the forearm I have forbidden medullary nailing within my jurisdiction because of the great number of failures, and I have greatly restricted its use for fresh compound fractures of the humerus With the availability of penicillin *the indication for medullary nailing can probably be liberalized* I have always rejected it for infected and draining fractures I wish to warn against medullary nailing in children

The circumstances leading to serious complications are emphasized for every type of fracture and are repeated in each chapter To obviate the necessity for long winded descriptions of the technique, I have generously illustrated the book. Excerpts from over 100 case histories with an average of eight X ray pictures apiece serve to follow the course of an entire case, sometimes covering a period of four years.

I wish to thank Professor Pernkopf and Dr Ehmann for their studies of the medullary cavities of the long bones and for placing their findings at my disposal

DR. LORENZ BÖHLER

Vienna, November 1947

TABLE OF CONTENTS

General Part

Special Part

GENERAL PART

OPERATIVE TREATMENT OF FRESH CLOSED FRACTURES WITH THE MEDULLARY NAIL OF KÜNTSCHER WITHOUT EXPOSURE OF THE FRACTURE FIELD

When Küntscher announced his new method of treating fresh closed fractures of the long bones with the medullary nail at the 64th Congress of the Deutsche Gesellschaft für Chirurgie at Easter 1940, comparing it with the extra articular nailing of femoral neck fractures, it became immediately evident to me that he had found the operative technique and the material for the treatment of properly selected shaft fractures of the long bones, a method for which I had been waiting a long time in the interest of a safer future for the operative treatment of these types of fractures (see page I/155*)

I therefore immediately adopted this method and am enthusiastic about the results in closed femoral fractures in the middle third. Also in strictly selected transverse fractures in the middle third of other long bones, good results can be obtained Callus formation, however, is usually delayed

Küntscher's method consists in the insertion of a long, strong and suitably shaped steel rod the "medullary nail" through a small incision distant from the fracture field into the bone in such a way that the fragments are so firmly united with each other that the limb as in nailed hip fractures can usually be lifted immediately and moved actively after 1–2 weeks in favorable cases even permitting functional use without additional external support (Figs 108–132) After bony consolidation this medullary nail can easily be removed by means of a minor procedure

Of chief importance is the fact that the introduction of the medullary nail, distant from the fracture site without direct exposure of the same minimizes the danger of infection with which present operative methods have been so heavily encumbered. This has been proven already in thousands of cases Furthermore, in properly selected cases the stability of the fracture is so great, in contrast to that provided

The figures preceded by I/ and II/ refer to the 1st and 2nd volumes respectively of the following

Bohler Technik der Knochenbruchbehandlung 5th to 11th German edition Maudrich, Vienna, 1937–1943 and

Bohler Tecnica del Tratamiento de las Fracturas, Editorial Labor Barcelona 1940 and

Bohler Tecnica del Trattamento delle Fratture, Casa Editrice Villardi Milano, 1940 and

Bohler Technique du traitement des fractures, Les éditions médicales de France Paris, 1944

The figures followed by an E refer to

Bohler The Treatment of Fractures, 4th English edition, John Wright and Sons, Ltd., Bristol England 1936.

by wires, plates and screws and short bolts, that additional external supports such as plaster of paris casts or traction are not necessary On the femur, the fragments can slide along the nail and be pressed against each other All injurious pulling, shearing, and pushing strains are eliminated by the medullary nail and only favorable pressure comes into action This stimulates the formation of callus as in hip nailing, whereas with the use of Lane plates it is frequently delayed because the screws prevent approximation of the fragments. Furthermore, by closed nailing the debris in the fracture field which is so important for the reconstruction of the bone, does not get lost and the periosteum and the surrounding tissues do not suffer additional damage and injury

The value of closed medullary nailing can be best proven by determining which of the usual damages that may follow for instance fractures of the femur can be avoided by medullary nailing

I **Loss of life**

Rapid *death* from the injury proper, for instance through loss of blood from the femoral artery or from other concomitant injuries, also through fat embolism or senile marasmus, cannot be prevented. Death from pulmonary embolism or pneumonia will become much rarer because the patients can move freely immediately after medullary nailing

Death from infection in compound fractures of the femur will become less common because the immobilization of the inflamed area is much more effective than with any other treatment Death from infection following operations on closed fractures with exposure of the fracture field is almost completely eliminated by closed nailing *Death* through infection arising from extension wires, pins or calipers, as reported previously and frequently found lately because many unskilled physicians have used skeletal traction is generally eliminated by medullary nailing

II **Loss of leg**

Loss of the leg because of the severity of the trauma or because of gangrene due to the injury or thrombosis of the femoral vessels cannot be prevented (Figs. 824–827)

Loss of the leg due to infection of fresh compound fractures following operation with exposure of the fracture field, and to infection originating from extension wires, pins or calipers is as a rule eliminated by the use of the medullary nail

III **Loss of full function of the leg**

1 *Infection* with sequestration and with sinus formation following compound fractures and following operation on fresh closed fractures with exposure of the fracture field cannot be prevented by medullary nailing For this reason I usually reject it and have prohibited it in my jurisdiction for fresh compound fractures of the lower leg and of the forearm Infection following traction by wires pins or calipers, or following pressure from adhesive plaster traction is prevented by the use of the medullary nail

2 *Pseudarthrosis* can usually but not always be avoided by painstaking technique in medullary nailing This is very important because an unbelievably large number of pseudarthroses have lately been produced by excessive skeletal traction

(Figs. 301–304, 352–356, 697–704 735–742, 754–783, 940–971) If, however, the technique used is not perfect medullary nailing can even produce a pseudarthrosis, especially on the lower leg (Figs 430–495)

3 *Mal position of the fragments* with shortening, angulation and rotation can be avoided by proper technique With defective technique and indication, shortening up to 3 cm (Figs 161–168), angulations up to 20° (Figs. 232–243 and 390–407) and rotation (Figs. 222–231) may occur

4 *Joint damage on the injured leg*, especially in the knee joint, but also in the hip, the ankle and tarsal joints and toes can be eliminated almost completely by a technically correct use of the medullary nail The possibility of early motion in the knee prevents impairment of movement and instability of this joint, the latter frequently resulting from marked shortening or from *excessive continuous traction*, applied below the knee for more than 4 weeks

5 *Joint damage on the non injured limb and the spine* will not develop because marked shortening will never occur with proper medullary nailing

6 *Nerve injuries* as frequently observed after operations on closed fractures with exposure of the fracture field and especially those caused by excessive traction, do not, as a rule occur with medullary nailing

7 *Vascular disturbances*, such as ischemia thrombosis and embolism will be rare with medullary nailing Edema and cyanosis will either not occur at all or be merely transient because the circulation returns to normal very quickly when early active motion and weight bearing are possible.

8 *Muscle atrophy* is merely transient with proper indication and technique, because the joints can be moved extensively as early as after 1–2 weeks (Figs. 108–132) Therefore the loose tissues around muscles tendons and joints do not become adherent and no decalcification occurs.

9 *Pressure ulcers and pressure scars* from plaster casts, splints or traction can only occur as exceptions because these additional supports are unnecessary in favorable cases.

The firm union of the fragments provided by the nail largely eliminates the dangers inherent in long recumbency, general and local damage to the circulation and the muscles, bone atrophy and limitation of joint motion The period of hospitalization and the entire treatment are markedly shortened in suitably selected cases.

From this compilation it is evident that **the closed medullary nailing of Küntscher is vastly superior to all previously known methods for the treatment of fresh closed fractures of the femoral shaft in properly selected cases**

In old fractures and in pseudarthrosis of the femur, the open medullary nailing is as a rule to be preferred to all other methods In fresh compound fractures medullary nailing has proven of value only in the femur I have forbidden its use for fresh compound fractures of the lower leg and of the forearm in my jurisdiction and have restricted it to a minimum for cases of the upper arm I have always rejected it for infected and discharging fractures

I welcome medullary nailing especially because in recent years more damage than good has been done by skeletal traction, although the latter can give excellent results if properly used.

The following questions are always asked concerning medullary nailing

1 What is the reaction of the bone marrow to the gross destruction?
2 What is the reaction of the bone to the large foreign body?
3 What is the situation as regards fat embolism?
4 How does callus develop in the presence of such a large foreign body?
5 How do the bone marrow and the bone react if infection occurs?

ad 1 *Medullary nailing and bone marrow* Küntscher in his reports has already shown that the bone marrow in contrast to bone tissue itself is not a highly differentiated therefore a less susceptible tissue, which regenerates rapidly This is particularly evident from the results of Walterhofer and Schramm, who in many cases of pernicious anemia completely removed the marrow of long bones (extirpation of marrow) This procedure was followed by an extraordinarily rapid regeneration of medullary substance The marrow therefore is not of great importance to the life of the bone It is merely a filling for the mechanically dead space, in juveniles with a blood forming organ and in adults with fat Küntscher has proven by numerous animal experiments, that bone marrow is not damaged by medullary nailing In humans some damage seems to occur occasionally as reported by Raisch and Slany (see pages 52 53)

ad 2 *Medullary nailing and bone* As X ray pictures show no pathologic changes take place in the bone if truly rust proof material is used

The damage which can be caused by rusting material is discussed on page 88 and shown in Figs 264–276

ad 3 *Medullary nailing and fat embolism* Clinical symptoms of fat embolism do not as a rule occur as proven in thousands of cases treated by medullary nailing Küntscher is of the opinion that this is due to the fact that as in Kirschner's splintering the medullary cavity is not put under pressure because the hole through which the medullary nail is introduced is considerably larger than the cross-section of the nail and because the bone marrow can flow out through the groove of the nail.

Maatz has proven histologically in animal experiments that slight fat embolisms do sometimes occur in the lungs kidneys and brain but that these are of no clinical significance.

If, however nailing is performed during shock it is possible that the slight additional fat embolism superimposed upon the other damages contributes to the fatal outcome (see page 8)

ad 4 *Medullary Nailing and Callus Formation* According to Küntscher the medullary nail does not interfere with callus formation He writes

"One might raise the objection that the damage done to the medullary cavity and to the endosteum causes considerable disturbance in the healing processes of the fractures having in mind the sad experiences with the use of pegs of ivory or bone in shaft fractures However the conditions prevailing with medullary nailing are radically different for various reasons

"a.) The pegs completely fill the medullary cavity so that no blood vessels can reach the callus and the compacta from the inside in the vicinity of the fracture

"b.) The endostium is destroyed by pressure from the peg. Nevertheless the bony pegs frequently healed in by uniting firmly with the cortex. However, the fracture line is not actually bridged by callus because the firmly impacted and healed in bone peg keeps the fragments apart acting even like an intact fibula in a lock pseudarthrosis of the tibia. The point of the bolt prevents the exertion of favorable pressure upon the callus. Strenuous use of the fractured limb then leads to a fatigue fracture of the bony peg.

"With the flanged nail the situation is entirely different. It does not completely plug the medullary cavity but on the contrary touches the endostium merely in three places (mostly in only 2 places because of slight curves in the shaft). These places are extremely small because of the sharp edges. Any possible pressure damage to the endostium and to the callus will therefore be exerted only from these small places; this is of no mechanical significance even if these sharp edges should cause a complete destruction of the surrounding substance to the extent of 1 mm. The periosteal callus would never be reached.

"Periosteal callus is the chief factor in the healing of a fracture but this callus will be transformed into bone only under favorable mechanical circumstances. Pauwels has proven this conclusively by calculations based on fractures of the femoral neck. The author likewise was able to prove this experimentally and by measuring the transmission of stresses through the bone. Bone formation is enhanced if the callus is subject to pressure stresses and if pushing and shearing as well as *excessive* pulling stresses are kept away from it as much as possible. This refers to the alternating pressure stresses caused by intermittent muscle action. As mentioned before, this is the essential principle of the nailing of the neck of the femur; it holds true, however, also for every other fracture. The firmly impacted ivory or bone peg prevents pressure upon the callus. A firmly seated flanged nail gradually loosens, as mentioned before in connection with the hip nail, so that the fracture surfaces are pressed against each other by muscle pull. *Therefore from a mechanical-biological standpoint this method appears the most favorable of all treatment methods for fractures.* On all sides of the fracture line pressure stresses are in action whereas the nail absorbs all injurious pushing, shearing and bending strains."

The assumption that callus formation is stimulated by the medullary nail has unfortunately not proven correct. In carefully reviewing our cases I found that the medullary nail, like any other foreign body, as a rule inhibits callus formation. Maatz too in his latest report on more than 300 cases of the clinic in Kiel found only 5 cases with increased callus formation and these were young people in whom periosteal callus formation usually tends to be marked and extensive under any method of treatment. A. W. Fischer found the average duration of treatment of fractures of the lower leg to be longer in those treated with the medullary nail than before its use.

Küntscher's opinion that the fragments are pressed against each other by muscular pull and weight bearing is correct for fractures of the femur. On the humerus the fragments are pulled apart by the weight of the arm, especially in older cases (Figs. 1064–1073). On the lower leg the bent medullary nail sometimes pries the fragments apart and prevents their approximation in the same way as a bone peg, and a fatigue fracture of the nail is not uncommon (Figs. 252–263, 430–441, 468–479, 1172–1179, 1210–1219). In contrast to this I encountered a fracture of the nail only once among almost 300 nailed fractures of the neck of the femur (Figs. II 1822–1826). I have not seen an extrusion of the hip nail since I gave it a new

shape in 1934 (Fig II/1680) whereas migrating of the medullary nail is not infrequent (Figs 232–243, 244–251, 1127–1134) In fractures of the lower leg A. W Fischer has seen a migrating of the medullary nail into the knee-joint.

Marked periosteal appositions after medullary nailing are a sign of a chemical (corrosion, Figs 264–276) or of a mechanical irritation (Figs. 390–429 and pages 88 128–136) These do not contribute to a quicker consolidation of the fracture

ad 5 *Medullary nailing and wound infection* The danger of wound infection is slight with *closed* nailing, with *open* nailing however, the danger is at least as great as with any other form of osteosynthesis As a rule it becomes even more dangerous, because the entire medullary cavity is exposed. In spite of this, however, the inflammations sometimes remain mild in character if the sutures at the fracture site and at the nailing site are quickly opened to relieve the pressure If this is not done in time, extensive soft tissue suppuration may develop with an occasional fatal outcome. The inflammation of the bone marrow, however, sometimes remains limited to the fracture site and the immediate surroundings of the nail and does not always involve the entire medullary canal In severe cases, however, typical medullary sequestra develop at the fracture ends For more about this see page 155 and Figs 480–526

Thus the dangers of *closed* medullary nailing appear slight in contrast to open nailing yet in studying the literature and in reviewing the case histories of more than 600 cases placed at my disposal by various hospitals, I found an unbelievable number of complications These were due to the facts that repeatedly the indication was too broadly interpreted that an inadequate armamentarium was used and that erroneous conceptions regarding callus formation and the anatomy of the medullary cavity prevailed. Many surgeons assumed that all previously valid laws governing treatment of fresh and old fractures and of pseudarthrosis could be disregarded with nailing although the new method has not changed these laws in the least

I will try to present the entire problem in the light of the experiences to date in order to reduce the number of failures which have occurred through disregard of several of Küntscher s directions

Indication for Closed Medullary Nailing

The prerequisites for closed medullary nailing are good general condition of the patient, healthy condition of the skin even in areas distant from the fracture site, and the absence of foci of infection in other parts of the body (e.g tonsillitis)

Femur Under these prerequisites all *closed transverse fractures* of the femoral shaft in the middle third (Figs 108–115) which is the narrowest area (isthmus) of the medullary canal are especially suited for medullary nailing Also suitable are all transverse fractures in the upp r and lower third of the femur that are at least 7 cm removed from the tip of the rochanter or from the knee joint

Also for *short or longer oblique fractures* within the isthmus or above the same the medullary nail provides sufficient stability (Figs 540–547) For good results in

oblique fractures in the lower third it is necessary to obtain very exact apposition of the fracture surfaces and to firmly anchor the medullary nail deep in the cancellous bone of the distal metaphysis (Figs 416–423)

Fragmented and comminuted fractures require additional continuous traction (Figs 574–581, 618–638, 649–656)

Spiral fractures with a long butterfly fragment are not suited (Figs. 582–589)

Old fractures of the femur with delayed callus formation due to excessive traction, as shown in Figs 301, 302, can sometimes be successfully treated by closed nailing even months afterward.

Some *re fractures of the femoral shaft* are also suitable

Aseptic *gunshot fractures of the femur* can be nailed after 2–3 weeks when all the wounds have healed (see pages 212 215)

Perhaps some *fresh gunshot fractures of the femur* with large wounds which are left wide open (see page 211) may be suitable

Tibia From a mechanical standpoint, *closed transverse fractures* of the middle third of the lower leg are particularly suited for closed nailing (Figs 816–823) They should be at least 10 cm removed from the upper or lower end of the tibia. Callus formation, however, is as a rule markedly delayed

Closed oblique fractures and spiral fractures in the middle third are equally suited. In the lower third the nail should as a rule be used only if the fragments are displaced laterally by the full width of the shaft or if they are difficult to reduce with continuous traction With the split nail of Maatz it may be possible to treat fractures even closer than 10 cm from the distal end of the tibia The old methods, however, are better and less dangerous.

Old transverse fractures in the middle third which are located somewhat lower than those shown in Figs 244–251 are sometimes suitable

Humerus Transverse fractures in the middle third (Figs 1010–1023) are best suited for closed medullary nailing Transverse fractures which are at least 9 cm removed from the elbow (Figs. 1064, 1065) or 5 cm from the shoulder (Figs 1002 1003) are also suitable

Spiral fractures in the middle third (Figs 1001–1005) may be nailed

For the humerus, too, the old methods have proven better than medullary nailing

Forearm From a mechanical standpoint, markedly displaced *transverse* and *oblique* fractures of both bones are suitable if they are at least 5–6 cm removed from the ends of the bones (Figs. 1101–1104 1105–1110)

Fractures of the ulna alone should be at least 3 cm from the proximal end or 6 cm from the distal end

Fractures of the radius alone should be at least 5 cm from the proximal end and 10 cm from the distal end. Fractures closer to the distal end (Figs 1117, 1118) are not suitable for closed medullary nailing

Experience has shown that on the forearm bones callus formation is particularly delayed by the use of the medullary nail

Fractures of the clavicle are not suited for closed medullary nailing

Spontaneous fractures after malignant bone tumors are very well suited for closed medullary nailing

Benign bone tumors, e g osteopathia fibrosa cystica localisata, are particularly suited for closed medullary nailing (Figs 784–791) if they are not located too close to the end of the bone Nailing may even effect a cure of the condition.

Tabes is no contra indication if the other requirements are assured.

From this exposition it is evident that closed medullary nailing is suited chiefly for transverse fractures of the femur in the middle third and for localized osteitis fibrosa cystica, whereas in other fractures it frequently entails more disadvantages than advantages

Contra indications to Closed Medullary Nailing

Contra indications with regard to the patient *Shock*, with small, rapid pulse pale appearance, cold sweat on the forehead, etc. as frequently seen in patients with multiple injuries, is an absolute contra indication against medullary nailing in cases of *closed fractures* The duration of the operation frequently accompanied by a cooling of the patient, the jarring caused by the driving of the nail the additional though slight fat embolism in the lungs or even in the brain, have caused a fatal outcome in not a few cases. In the literature as well as in personal conversations the view is frequently expressed that these patients would have died anyway without medullary nailing I do not share this opinion because if it was evident that the patient was destined to die, there was no urgent necessity to treat his fractured bone with medullary nailing The peace of the dying should not be disturbed by hammer blows On the other hand when I read in the literature or in case histories that patients in shock were subjected to a nailing operation lasting 1–2 hours I am inclined to conclude that these patients must have been in such good general condition that they would probably have survived the injury had they not been exposed to this prolonged and, for a patient in shock, rather serious operation. If in these cases a pin or wire traction is applied under local anesthesia, the procedure consumes only 1 minute without imposing an additional burden upon the circulation and the general condition the patients can then be successfully treated for shock

Closed medullary nailing must not be carried out in fresh closed fractures in a patient under severe shock as is usually the case in multiple injuries because it may lead to a fatal outcome

When the shock was only slight the pulse recovers after a few hours again becoming slow and full, if the patient has been kept warm and restored properly Then is the time for nailing unless one prefers to wait even longer

Serious systemic diseases are not as a rule an indication for medullary nailing as some surgeons insist but rather a contra indication

In the presence of *inflammatory conditions of the respiratory gastro-intestinal or genito-urinary organs* closed medullary nailing must not be carried out because hematogenous infection of the bone marrow may result. Particular attention must be paid to tonsillitis

In *infectious conditions of the skin*, especially furunculosis, medullary nailing must not be performed because of the danger of metastatic infection

If *burns* are present, especially on the injured limb, nailing should not be done (Figs. 169–178 and 649–656)

In the presence of *wounds in other parts of the body*, medullary nailing should not be performed until those wounds are completely healed, i e about 14 days after the injury, because otherwise late inflammation and metastatic infection may occur (see page 151)

In the presence of *deep abrasions of the skin* over the fracture site which were not excised and sutured within the first 6 hours, nailing must not be done because, especially on the shin bone and on the forearm, a possible subsequent necrosis of the skin may lead to an exposure of the immediately underlying fracture and thus bring about infection

If *marked swelling with bleb formation* is present, nailing must not be done It is necessary to wait until the swelling has subsided If tension blebs have formed, medullary nailing should not be considered

If *varicosities are present on the lower leg*, nailing should not be performed. Stotz saw a fatal outcome in a case of this kind (see page 152)

Contra indication with regard to the bone All the following fractures are not suited for nailing

Femur those less than 7 cm from the tip of the trochanter or from the knee joint.

Tibia those less than 10 cm from the proximal or distal end

Humerus those less than 5 cm from the proximal end or less than 9 cm from the distal end

Forearm those less than 5 cm from the proximal or distal end.

Ulna (only) those less than 3 cm from the proximal end and less than 6 cm from the distal end

Radius (only) those less than 5 cm from the proximal and less than 10 cm from the distal end.

Spiral fractures with a long butterfly fragment (Figs. 161–168, 570–573, 582–589) are not suitable for closed medullary nailing

Some cases of *bone diseases, e g Paget's disease,* cannot be nailed if the medullary canal is not patent As a rule, however fractures in Paget's disease are transverse and therefore particularly suited for medullary nailing

Tabes is no contra indication if the other requirements are met.

Contra indications with regard to the physician Only a physician with sufficient experience in bone surgery is entitled to attempt medullary nailing As is evident from numerous reports in the literature, this procedure is frequently not so simple as it was occasionally represented in the beginning

There must be on hand a sufficient selection of medullary nails furthermore, two X ray apparatus and the instruments enumerated on pages 22–26 Efficient extractors and a steel saw (Figs 70, 71 and 83) are particularly important. The following remarks sometimes found in histories of cases which sooner or later show complications are not justifiable, viz The medullary nailing had to be performed

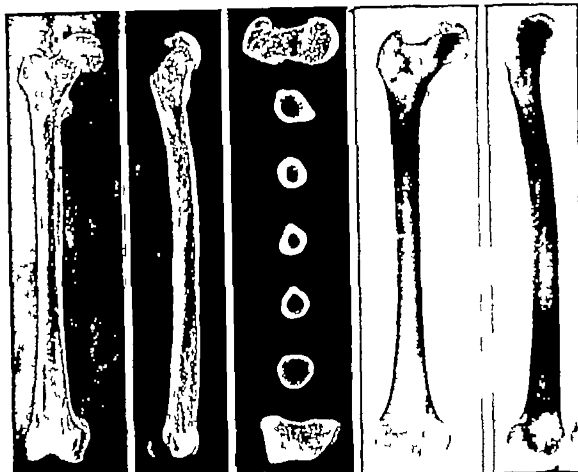


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

Fig 1 Frontal section through the femur
Fig. 2. Sagittal section through the femur
Fig 3 Seven transverse sections through the femur
Fig. 4. A-P X-ray picture of the femur
Fig 5 Lateral X ray picture of the femur

All 5 pictures show that the narrowest region (isthmus) of the medullary canal is located just proximal from the middle of the femur In adults it varies from 8–16 mm. From the isthmus the medullary canal rapidly widens distally proximally more gradually In the transverse section the isthmus is approximately circular Between the proximal and middle third it is oval in the anterior-posterior direction. The shaft contains only scanty trabeculae only small coarse trabeculae on the wall. In the metaphases the cancellous bone becomes dense. For the determination of the thickness of the nail, the isthmus must be measured on the X ray pictures and the length of the nail is determined by the length of the bone. In fractures below the middle, if the medullary nail does not reach to the epiphyseal line, it has no anchorage in the wide medullary space of the metaphysis.

although no medullary nail of proper length and thickness was available. Or The nailing had to be performed even though the X ray apparatus failed (the operation was started with only one apparatus instead of two) Concerning such circumstances it must be emphasized that medullary nailing is never an emergency procedure If the necessary equipment is not available nailing must not be performed

Closed fractures in children should not be nailed in my opinion because of the greatly increased danger of acute osteomyelitis in children (see page 151) Furthermore fractures heal very rapidly in childhood For instance, a fracture of the femur

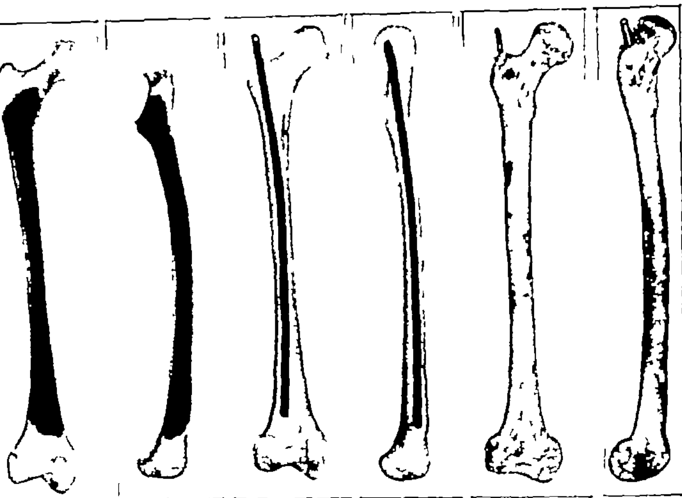


Fig. 6 Fig 7 Fig 8 Fig 9 Fig 10 Fig. 11

Figs. 6 7 Medullary space filled with barium according to Ehmann. This illustrates clearly the places at the proximal and distal ends of the bone where the nail will obtain anchorage in addition to that offered by the isthmus above the middle of the shaft.

Figs. 8, 9 Position of the nail in the medullary canal. Although it is thick it has followed the shape of the bone and is bowed. Proximal from the middle it completely fills the cavity and provides a firm support in this region. In the distal part, it lies against the anterior and lateral wall and thus obtains a much better hold than if it were located in the center (of the cavity) where the cancellous bone forms a much wider mesh-work. In fractures distal from the middle, a longer nail must be used in order to reach the epiphyseal line.

Figs. 10 11 Nailing site in the posterior part of the crest of the greater trochanter For purposes of illustration the nail was left protruding 4 cm. actually it should be inserted to within 2 cm. of the bone so as not to interfere with full motion.

in a child under 10 years will unite firmly in 3–5 weeks if the weight used for continuous traction was not excessive Furthermore in those children s fractures which are suited for medullary nailing limitation of motion or other permanent disturbances never occur with proper treatment.

The Medullary Cavity of the Long Bones

When I became interested in finding exact data concerning the shape and extent of the medullary cavity its relation to the cancellous parts of the bone and the thickness of the wall of the shafts of the long bones I was unable to find it in the text books and atlases of anatomy and joint mechanics In all these works only the cancellous bone ends and usually only a frontal cut were represented because such

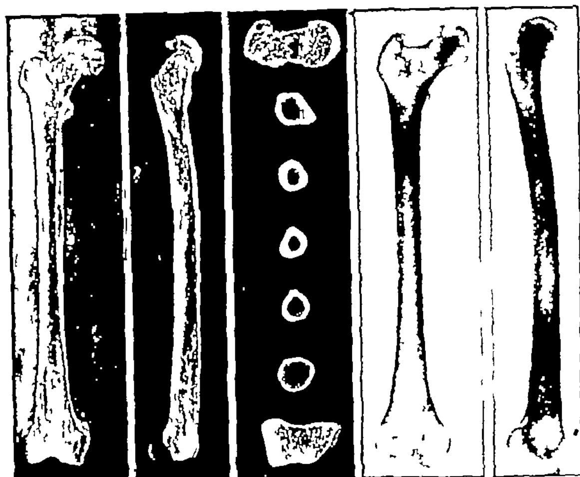


Fig 1 Frontal section through the femur
Fig 2 Sagittal section through the femur
Fig 3 Seven transverse sections through the femur
Fig 4 A P X ray picture of the femur
Fig 5 Lateral X ray picture of the femur

All 5 pictures show that the narrowest region (isthmus) of the medullary canal is located just proximal from the middle of the femur In adults it varies from 8–16 mm. From the isthmus the medullary canal rapidly widens distally proximally more gradually In the transverse section the isthmus is approximately circular Between the proximal and middle third it is oval in the anterior-posterior direction The shaft contains only scanty trabeculae, only small coarse trabeculae on the wall. In the metaphases the cancellous bone becomes dense For the determination of the thickness of the nail, the isthmus must be measured on the X ray pictures and the length of the nail is determined by the length of the bone. In fractures below the middle, if the medullary nail does not reach to the epiphyseal line, it has no anchorage in the wide medullary space of the metaphysis.

although no medullary nail of proper length and thickness was available. Or The nailing had to be performed even though the X ray apparatus failed (the operation was started with only one apparatus instead of two) Concerning such circumstances it must be emphasized that medullary nailing is never an emergency procedure If the necessary equipment is not available nailing must not be performed

Closed fractures in children should not be nailed in my opinion because of the greatly increased danger of acute osteomyelitis in children (see page 151) Furthermore fractures heal very rapidly in childhood For instance, a fracture of the femur



Figs. 17, 18 Barium filling of the medullary canal according to Ehmann. This illustrates the areas where the nail can get a firm anchorage

Figs. 19 20. A nail of sufficient thickness and length was inserted from proximal. It penetrates into the bone from the front, touches the posterior wall at the junction between the proximal and middle third whence it is deflected forward. It reaches to the plainly visible epiphyseal line and therefore its point has a satisfactory hold in the bone

Figs. 21 22 Nailing site just medial to the tibial tuberosity For better illustration the nail protrudes 3½ cm. actually it is driven to within 1½ cm. of the bone otherwise it causes pressure against the skin and may perforate it.

4 Type of transition of the medullary canal into the spongiosa (whether sudden or gradual)

5 Thickness of the cortical bone

6 Variations (sex differences, age differences, etc)

Thirty series of long bones including femur, tibia clavicle humerus, ulna and radius were examined In order to obtain such pictures as are taken in the living for the purpose of measurements, X ray pictures were first made of the bare bones in two planes, transversely and at a right angle to this. For a clearer delineation of the canal the medullary cavity of all bones was then filled with a barium sulphate mass and another series of pictures was taken in the same positions as previously In this way it was possible to determine to what extent the medullary canal was partly or completely devoid of spongiosa and where the narrow meshwork of the

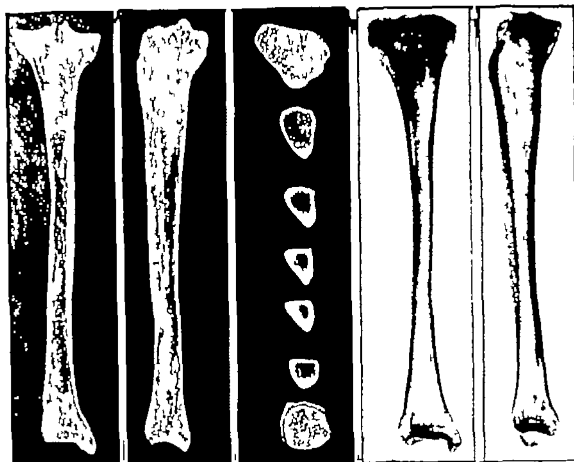


Fig. 12 Fig 13 Fig 14 Fig 15 Fig. 16

Fig 12. Frontal section through the tibia.
Fig 13 Sagittal section through the tibia.
Fig 14. Seven transverse sections through the tibia.
Fig. 15 A-P X ray picture of the tibia.
Fig 16 Lateral X-ray picture of the tibia.

All 5 pictures show that the almost circular isthmus of the medullary canal is located between the middle and the distal third. The diameter varies in adults from 8–12 mm. The middle third is comparatively narrow the proximal and distal thirds are very wide. Cancellous bone is scarce in the shaft, showing coarse trabeculae on the walls. Sometimes the cavity is closed transversely by one or two partitions at the junction between the middle and distal third, preventing the passage of barium In the ends of the bone, the cancellous trabeculations are denser A nail inserted from proximally will in fractures distal from the middle obtain a strong hold only if it reaches to within the epiphyseal line. In fractures within the proximal quarter of the bone, the nail should preferably be inserted from distally It should then reach also to the proximal epiphyseal line. Such fractures, however are not suited for medullary nailing

questions as arose from medullary nailing had never been posed before Therefore I requested the director of the Anatomical Institute of the University of Vienna, Professor Pernkopf to clarify these points He entrusted Dr Ehmann with this time-consuming study which required insight dexterity and persistence and has evolved the following outline for the description of bones

1 Width of the medullary canal
2 Direction of the medullary canal (angles)
3 Length of the medullary canal



Figs. 17 18. Barium filling of the medullary canal according to Ehmann. This illustrates the areas where the nail can get a firm anchorage

Figs. 19 20 A nail of sufficient thickness and length was inserted from proximal. It penetrates into the bone from the front, touches the posterior wall at the junction between the proximal and middle third whence it is deflected forward. It reaches to the plainly visible epiphyseal line and therefore its point has a satisfactory hold in the bone

Figs. 21 22 Nailing site just medial to the tibial tuberosity For better illustration, the nail protrudes 3½ cm. actually it is driven to within 1½ cm of the bone otherwise it causes pressure against the skin and may perforate it.

4 Type of transition of the medullary canal into the spongiosa (whether sudden or gradual)

5 Thickness of the cortical bone

6 Variations (sex differences, age differences, etc.)

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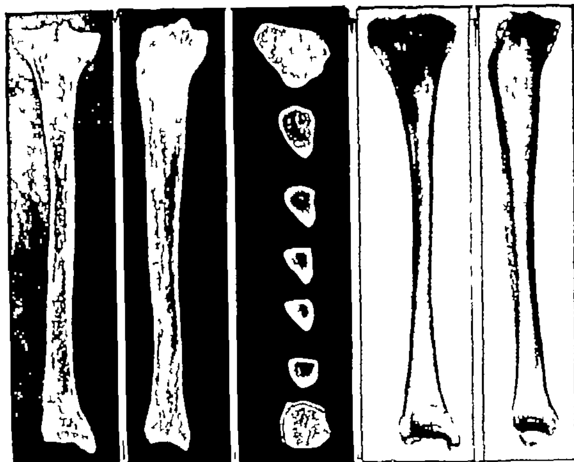


Fig. 12. Frontal section through the tibia.
Fig. 13 Sagittal section through the tibia.
Fig. 14. Seven transverse sections through the tibia.
Fig 15 A-P X ray picture of the tibia.
Fig 16 Lateral X-ray picture of the tibia.

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1 Width of the medullary canal
2 Direction of the medullary canal (angles)
3 Length of the medullary canal



Figs. 28, 29 Barium filling of the medullary canal according to Ehmann. In addition to the isthmus the nail obtains a firm hold in the areas not filled by this mass.

Figs. 30 31 A nail of sufficient length and thickness has been driven from distally into the isthmus. It passes through the proximal third of the canal which is free of cancellous bone to the epiphyseal line where it obtains a firm hold. If it does not reach so far proximally it will move within the canal and may even break as in Figs. 476 477

Figs. 32, 33 Nailing site on the dorsal surface above the fossa olecrani For better illustration the nail protrudes 3½ cm. from the bone actually It should be driven to within 1½ cm., otherwise it would interfere with motions of the elbow

the macerated bone becomes over-exposed even when very soft radiation is used For this reason the cortex appears thinner than it actually is

Following the X ray studies, frontal sections were made through all the bones After removal of the barium they were photographed (Figs 1, 12 23, 34 45 56)

From the bones of the other side sagittal cuts were made (Figs 2, 13, 24 35, 46 57)

Of bones which in their external shape (length, thickness and curve) and which in the X ray pictures (arrangement of the compacta and spongiosa, width of the

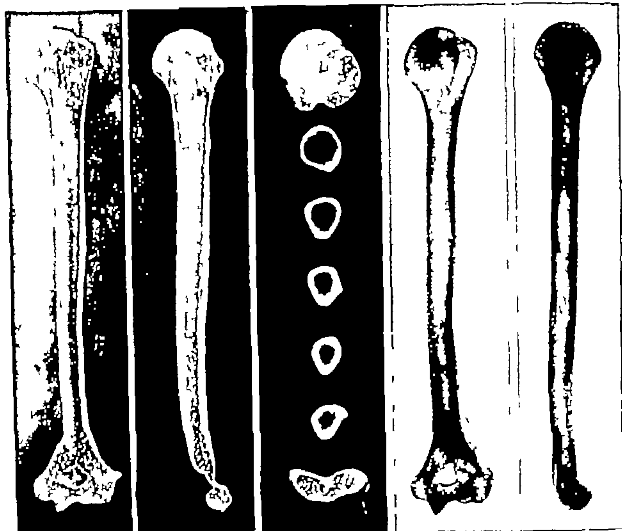


Fig 23 Fig. 24 Fig 25 Fig 26 Fig 27

Fig. 23 Frontal section through the humerus.
Fig. 24 Sagittal section through the humerus.
Fig 25 Seven transverse sections through the humerus.
Fig. 26 Antero-posterior X-ray picture of the humerus.
Fig 27 Lateral X ray picture of the humerus.

All 5 pictures show that the narrowest, almost circular area of the medullary canal is located in the distal third. In adults it varies from 6–9 mm. From the isthmus the canal widens proximally and the wall of the bone becomes thinner The nail obtains its firmest hold if it is inserted through the distal third and if it reaches proximally to the epiphyseal line of the head

cancellous bone begins which may offer the nail a firm anchorage beyond that furnished by the isthmus of the medullary canal (Figs 6 7 17 18 28, 29, 39 40, 50 51, 61 62) From these pictures it is clearly evident how far the medullary nail must reach if it is to be used in fractures which calculated from the site of insertion of the nail are located beyond the narrowest point of the bone The thickness of the compacta is not accurately represented in these X ray pictures because only the inner surface of the cortical bone substance is sharply outlined against the very opaque barium sulphate mass while the outer outline of the bone is indefinite because



Fig 39 Fig 40 Fig 41 Fig 42 Fig 43 Fig 44

Figs. 39 40 Barium filling of the medullary canal according to Ehmann

Figs. 41 42. The nail, 3 mm thick, fills the medullary canal everywhere almost completely and provides a firm support in every location if it is of sufficient length.

Figs. 43 44 Nailing site over the middle of the olecranon The nail protrudes 2 cm from the bone for better illustration actually it is driven to within 1 cm. otherwise it would cause pain at the elbow

medullary canal at various levels and especially the narrowest area (isthmus) of the medullary canal The measurements varied greatly according to sex, constitution age, size and muscular development

The only factor for the determination of the thickness of the nail is the width of the isthmus of the medullary canal This can be measured quite accurately from X ray pictures. For the length of the medullary nail it was originally considered sufficient for it to penetrate 4–8 cm into the fragment on the other side of the fracture line As clinical experience and study of the medullary cavity have shown, this length is sufficient for some fractures located between the point of insertion of the nail and the isthmus of the medullary canal, but for all others it is not adequate For most fractures it is necessary that the nail reach to the level of the previous epiphyseal line which in most bones is readily visualized in X ray pictures and on frontal and sagittal sections

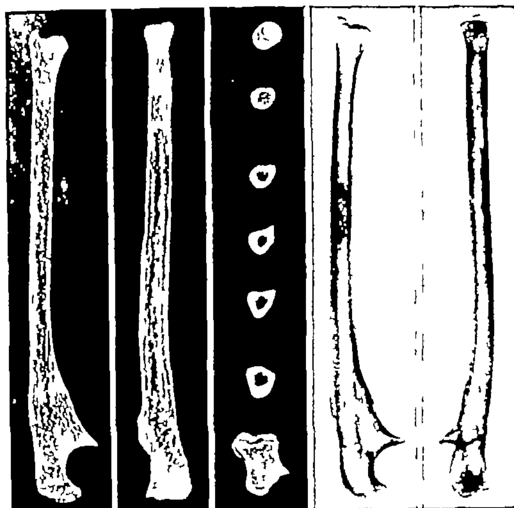


Fig 34 Fig 35 Fig 36 Fig 37 Fig 38

Fig 34 Sagittal section through the ulna.
Fig 35 Frontal section through the ulna.
Fig 36 Seven transverse sections through the ulna.
Fig 37 Lateral X ray picture of the ulna.
Fig 38. A P X ray picture of the ulna.

All 5 pictures show that the medullary canal is of approximately equal width throughout the shaft. Its diameter varies in adults from 2-5 mm If the nail is driven through the olecranon, it obtains a firm hold everywhere.

medullary canal) were most nearly similar to those previously studied a transverse section was made through each metaphysis another through the middle and two each above and below the middle through the shaft at equal distances (Figs. 3, 14, 25, 36 47 58)

Furthermore we drove a medullary nail of proper thickness and length through one of each of the long bones and took photographs from the front and from the side (Figs 10 11 21 22 32 33 43 44 54 55 65 66)

Finally X ray pictures of these bones with the inserted medullary nail were taken in both planes (Figs 8 9 19 20 30 31 41 42 52 53 63 64)

From each bone we thus obtained exact data concerning the distribution of the compacta and spongiosa the thickness of their walls the width and shape of the



Fig. 50 Fig 51 Fig 52 Fig 53 Fig. 54 Fig 55

Figs. 50 51 Barium filling of the medullary cavity according to Ehmann

Figs 52 53 The nail 3 mm. thick is inserted through the dorsal surface of the distal end of the radius and reaches into the proximal third The middle third of the canal is almost completely filled with the nail

Figs. 54 55 Nailing site on the dorsal surface of the distal end of the radius. It is located somewhat too far from the joint line. The protruding end must be bent upwards, otherwise it will work its way into the bone by its elasticity

For determining the thickness of the medullary nail it is necessary to consider the curve in the sagittal plane, in addition to the isthmus of the canal If this curve is decidedly marked, a thinner nail must be chosen since a thick nail will not bend sufficiently and will therefore become wedged when driven in

In determining the length of the nail one must know that only for fractures in the upper third, will a nail be sufficient which penetrates 4–8 cm beyond the isthmus For all fractures distal from the middle the nail must as a rule reach to the epiphyseal line because the spongiosa in the metaphysis especially in its central parts is still so wide meshed that it will give sufficient anchorage only in exceptional cases (Figs 410–413) but usually permit later angulations The X ray pictures will then show how the tip of the nail gradually travels from one side of the bone to the other (Figs 238–242 390–405) thus comminuting the spongiosa.

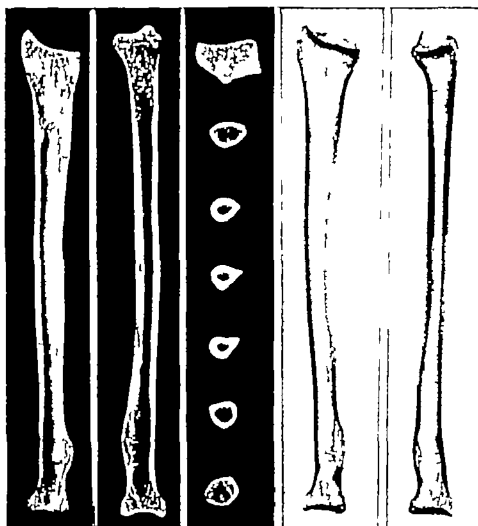


Fig 45 Frontal section through the radius.
Fig 46 Sagittal section through the radius.
Fig 47 Seven transverse sections through the radius.
Fig 48 A P X ray view of the radius.
Fig 49 Lateral X ray picture of the radius.

These 5 figures show the narrowest part of the medullary canal located in the middle third. It is of oval shape with the greater diameter lying in the radio-ulnar direction. The diameter of the isthmus varies in adults from 2–5 mm. The nail provides the firmest support if it is inserted from the dorsum of the distal end of the bone and driven to near the head of the radius.

On the *femur* the narrowest region of the medullary canal (isthmus) is located immediately proximal from the middle (Figs 1–9) The usual diameter is from 8–12 mm but may be as wide as 16 mm In this region the cortex has its greatest thickness Proximally the cavity becomes only slightly larger toward the minor trochanter After that it widens rapidly and is filled with a dense net of trabeculae Distal from the middle the canal widens gradually toward the distal metaphysis. The distal half of the cavity is filled with wide meshed spongiosa trabeculae The distal end shows a dense spongiosa on the walls which becomes thickest beyond the epiphyseal line



Fig 50 Fig 51 Fig 52 Fig. 53 Fig 54 Fig 55

Figs. 50 51 Barium filling of the medullary cavity according to Ehmann.

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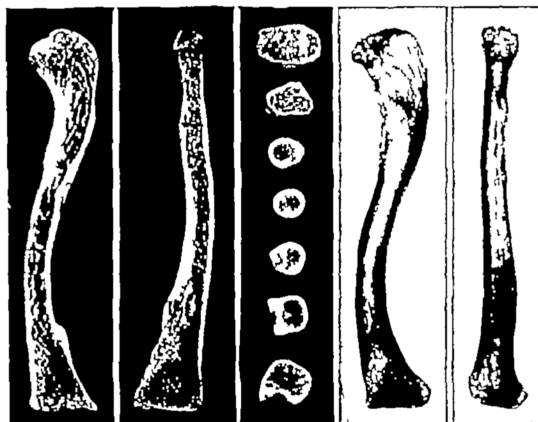


Fig. 56 Fig. 57 Fig. 58 Fig. 59 Fig. 60

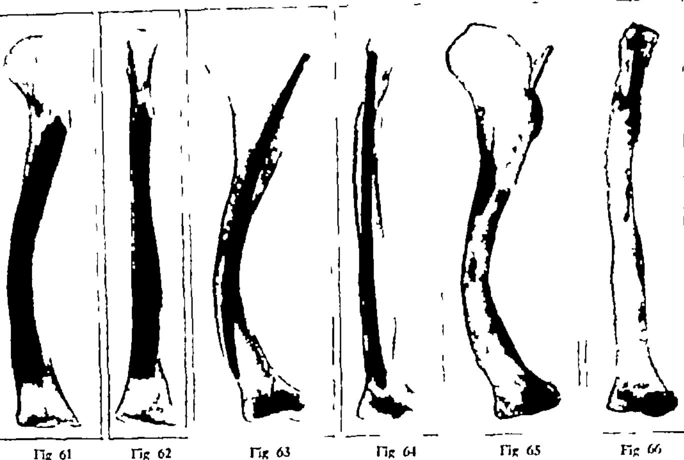
Fig 56 Frontal section through the clavicle.
Fig. 57 Sagittal section through the clavicle.
Fig 58 Seven transverse sections through the clavicle.
Fig 59 A P X-ray picture of the clavicle.
Fig. 60 Lateral X ray picture of the clavicle.

All 5 figures show that in contrast to other long bones, almost the entire medullary canal is filled with strong trabeculae. Only at the sternal end can a short medullary canal be made out. The isthmus is located in the middle third. Its diameter varies in adults from 3–7 mm. The nail obtains its firmest hold if it is inserted at the most anterior point of the acromial end and driven into the middle of the sternal third.

On the *tibia* the isthmus lies between the middle and the distal third (Figs 12–20) The diameter varies between 8–12 mm The middle third is comparatively narrow From there the canal gradually expands proximally and distally The middle third contains only a few trabeculae whereas the walls of the proximal and distal thirds of the shaft are lined with them At the metaphyseal ends the network of trabecula tions becomes gradually thicker reaching maximum density beyond the epiphyseal line At the proximal end this line is located 12–15 mm from the joint line and at the distal end 8–10 mm from the joint line

The spongiosa in the proximal third of the shaft is much stronger on the anterior than on the posterior wall and therefore gives good anchorage to the nail at the usual site of its insertion

On the *humerus* the isthmus is located in the distal third (Figs 23–31) The diameter distally from this is that of a transverse oval measuring 6–9 mm At the narrowest point there are strikingly thick trabeculae in the trochlea they again



Figs. 61 62. Barium filling of the medullary cavity according to Ehmann
Figs. 63 64 The nail 4 mm. thick has followed the curve of the bone and shows marked bowing
Figs. 65 66 Nailing site at the apex of the curve of the bone at the acromial end.

become more fine meshed Proximally the medullary canal expands gradually In the shaft area there are strikingly few trabeculae Only at the metaphyseal ends do the trabeculations again become close and are, as in all bones densest beyond the epiphyseal line For this reason a nail inserted from the distal end must reach up ward into the epiphyseal line

On the *ulna* the isthmus is in the middle third but the distal third is not much wider (Figs 34–42) The diameter varies between 2–5 mm In the shaft the tra beculae are sparse Only at the metaphyseal ends is there a dense network of trabeculations.

On the *radius* the isthmus is located at the border between the proximal and middle third (Figs 45–53) From there the canal quickly widens proximally as well as distally The diameter varies from 2–5 mm As on the ulna, only the joint ends are filled with dense spongiosa

On the *clavicle* the isthmus is in the middle third, the diameter varies between 3–7 mm (Figs 56–64) Toward the ends the medullary canal widens rapidly The entire canal is filled with strikingly coarse spongiosa trabeculae, which in many bones fill the greater part of the medullary canal At the sternal end an actual medullary cavity is found in comparatively few bones

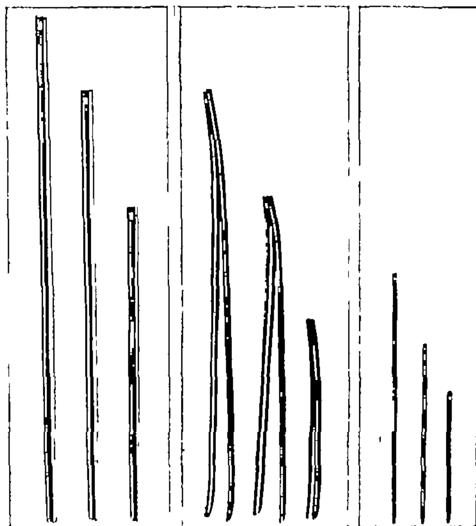


Fig 67 Fig 68 Fig. 69

Fig 67 Kuntscher's medullary nails for the femur with guide groove, rounded tip and an eye for extraction at the driving end. Length 34–54 cm with 2 cm. intervals. Thickness 8 9 and 10 mm. The length and thickness is marked on an attached metal tag

Fig 68. Double medullary nails for the tibia The tips are slightly bent. Length 25–36 cm. with 1.5 cm. intervals. Thickness 6 and 8 mm Double nails for the humerus are 20–28 cm. long and 5–7 mm. thick.

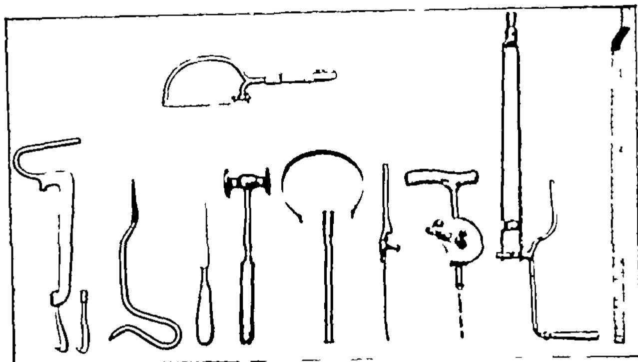
Fig. 69 Medullary nails for radius ulna and clavicle Length 8–25 cm., thickness 3 3.5 and 4 mm.

Apparatus and Instruments

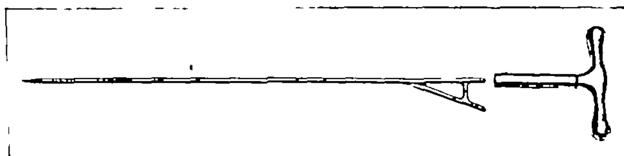
Medullary nailing can be performed correctly only if the necessary reduction apparatus instruments X ray apparatus and medullary nails of various sizes and in sufficient number are available

For medullary nailing the following items are needed

1 Local anesthesia (Figs 105 E I/124 and page I/99)
2 Good X ray pictures exactly from the front and from the side preferably 15 x 40 cm in size
3 Reduction apparatus for the femur and lower leg Linsmayer s (Figs 92 93), Böhler s (Figs 95 96) or Wittmoser s (Figs 99–103) or other models
4 Reduction apparatus for the humerus Linsmayer s (Fig 94) Böhler s (Fig 97) Wittmoser's (Figs 99–103) or other models



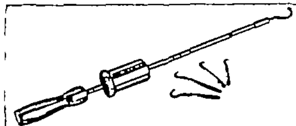
Figs. 70–80



Figs 81 82

Fig 70 Above hack saw for cutting off nails which can neither be driven in further nor extracted.
Fig 71 Küntscher's extractor with 2 hooks.
Fig. 72 Awl with curved handle for piercing the bone
Fig. 73 Straight awl for piercing the bone
Fig 74 Heavy hammer weighing 500 Gm
Fig. 75 A hardened driving punch with a recess, 2 cm deep
Fig. 76 Curved spring clip after Güttner for the protection of the skin during the driving of the nail into the tibia.
Fig. 77 Küntscher's handle for holding and driving medullary nails.
Fig 78 Hand drill
Fig 79 Küntscher's winch for extracting nails.
Fig. 80 Metal ruler for measuring.
Fig. 81 Guide pin Length 44–54 cm. thickness 3 3.5 4 and 5 mm.
Fig. 82. Güttner's sturdy slotted handle for the guide pin Two sizes are needed.

5 Reduction apparatus for the forearm e g Böhler's (Fig 98) or other models
6 Two mobile X ray apparatus (Figs 103, 528 804, 998, 1098)
7 Two fluoroscopic screens (Fig 103)
8 One hand fluoroscope (Figs 104–107)



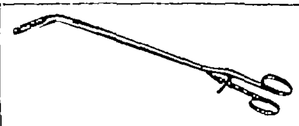


Fig 83 Fig 84

Fig. 83 Stör's extractor hammer

Fig 84. Jorg Bohler's forceps for holding the hooks firmly to the nail during extraction. The jaws are fenestrated to accommodate the points of the hooks and are large enough to grasp the thickest nail and hook.

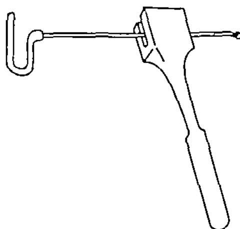


Fig. 84-a

Fig. 84-a. Extractor hook and extractor hammer of Küntscher and Pohl

9 Lead aprons and lead gloves
10 Sterile cases for the X ray cassettes
11 A rapid developer (page 35)
12 A triangle rule (Fig I 57) and an ordinary straight rule of celluloid.
13 Küntscher medullary nails for femur tibia humerus ulna radius and clavicle in various lengths and thicknesses (Figs 67–69)
14 Sharp and blunt guide wires of various lengths and thicknesses with proper handles (Figs 81 82)
15 A straight and a curved awl for piercing the bone (Figs 72 73)
16 A hand drill (Fig 78)
17 Or preferably an electric drill with round burr (Figs. I 103–106)
18 A hammer weighing at least ½ kg (Fig 74)
19 A driving punch with a recess (Fig 75) and an ordinary driving punch
20 A steel saw for sawing off medullary nails which can neither be driven forward nor extracted (Fig 70)
21 A tool for extracting Küntscher nails (Fig 71)
22 Or a Stör hammer extractor (Fig 83)
23 *Or a Pohl nail extractor*

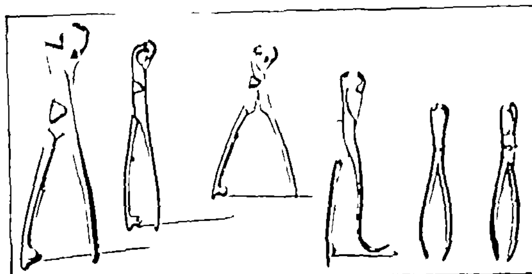
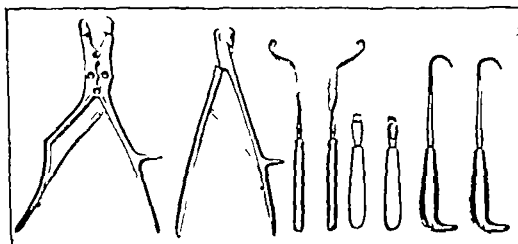


Fig 85 Fig 86 Fig 87

Fig 85 Three Lambotte bone holding clamps of different sizes with locking ratchets
Fig 86 Ordinary bone-holding clamps with locking ratchet adjustable
Fig 87 Two ordinary non locking bone holding forceps



Figs 88-91

Fig 88 Two strong Luer bone rongeurs.
Fig 89 Two Hohmann bone elevators.
Fig 90 Two Lambotte periosteal raspatories.
Fig 91 Two strong Langenbeck single pronged bone hooks.

24 Forceps for holding the hook to the nail by Jörg Bohler (Fig 84)

25 A metal ruler for determining the length of the guide wire and of the medullary nail (Fig 80)

26 A spring clip for protecting the skin while driving nails (Fig 76)

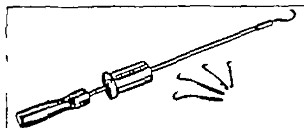
For open medullary nailing with exposure of the fracture, the following additional equipment is needed

27 Lambotte bone holding forceps of various sizes with locking ratchet (Fig 85)

28 Simple bone holding forceps (Figs 86 87)

29 Strong Luer rongeurs (Fig 88)

30 Straight chisels and gouges



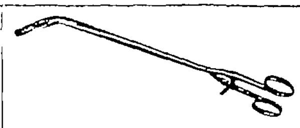


Fig. 83 Fig. 84

Fig. 83 Stör's extractor hammer

Fig. 84 Jörg Bohler's forceps for holding the hooks firmly to the nail during extraction. The jaws are fenestrated to accommodate the points of the hooks and are large enough to grasp the thickest nail and hook.

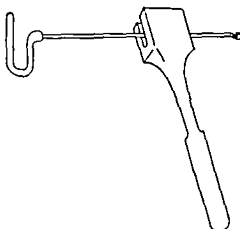


Fig. 84-a

Fig. 84-a. Extractor-hook and extractor hammer of Küntscher and Pohl

9 Lead aprons and lead gloves
10 Sterile cases for the X ray cassettes
11 A rapid developer (page 35)
12 A triangle rule (Fig I 57) and an ordinary straight rule of celluloid
13 Küntscher medullary nails for femur tibia humerus, ulna, radius and clavicle in various lengths and thicknesses (Figs 67–69)
14 Sharp and blunt guide wires of various lengths and thicknesses with proper handles (Figs 81 82)
15 A straight and a curved awl for piercing the bone (Figs 72 73)
16 A hand drill (Fig 78)
17 Or preferably an electric drill with round burr (Figs. I/103–106)
18 A hammer weighing at least ½ Kg (Fig 74)
19 A driving punch with a recess (Fig 75) and an ordinary driving punch
20 A steel saw for sawing off medullary nails which can neither be driven forward nor extracted (Fig 70)
21 A tool for extracting Kuntscher nails (Fig 71)
22 Or a Stör hammer extractor (Fig 83)
23 Or a Pohl nail extractor

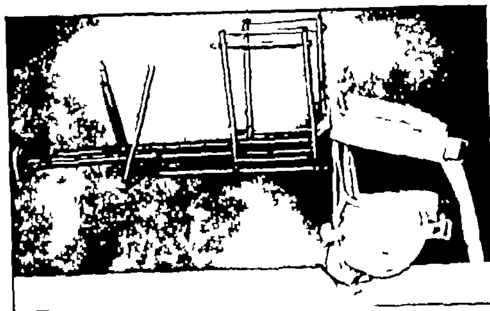


Fig 91

Fig. 91 Linsmayer's screw traction apparatus for the upper arm with reduction frame attached.

ad 2 The technique of taking X ray pictures, their number and arrangement identification and storage has been discussed on pages I 59-72

ad 3-5 Linsmayer has described his reduction apparatus in Der Chirurg, No 2 1943 as follows

"I have used Böhler's apparatus and modified it in such a way that lateral traction together with longitudinal traction can be exerted in every direction The modified apparatus is built upon a double-cross-shaped base of a heavier band iron To this base at the upper end are attached two inclined metal tubes into which the support for the popliteal space or the perineum can be slid for adjustment in height (Fig 92) For the knee the Z-shaped support of Böhler's original traction apparatus is used for the perineum a thicker roll is employed The required longitudinal traction is exerted by means of a strong screw which is attached to the base of the apparatus and moves a hook-carrier adjustable to the necessary height footward The hook at the end of this carrier is attached to a leather foot hitch so that the traction of the screw is transmitted to the leg to be extended (Figs 529 and 805)

A small carriage with a clamp mounted on rollers runs on a pair of rails attached along the middle of the base The tube of the Siemens portable X ray apparatus is clamped to this carriage for convenient fluoroscopy from below upward in any desired position (Figs 92 93 and 805) In order to provide the necessary lateral tractions for exact reduction of femoral and leg fractures in addition to longitudinal traction an attachment was constructed for the slightly changed Böhler screw traction apparatus It consists of a frame made of four metal rods connected with each other which can readily be attached to the base of the apparatus (Fig 93) Four steel rods about 58 cm. long are attached to both sides in the long axis these can be turned and are provided with a locking device Around these rods two bandages are slung in opposite directions By turning these bars and thus winding up and shortening the bandages an exactly controllable degree of traction and counter traction in the desired direction can be exerted to either side as well as forward and backward The arrangement of these rods is such that lateral fluoroscopy is not interfered with (Fig 805)

For nailing of the lower leg the patient lies on his back with the knee flexed as on the Böhler traction apparatus (Fig. 804) For nailing of the femur the patient is placed on his side with

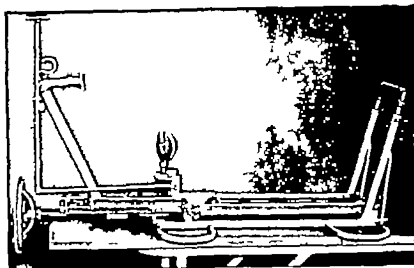


Fig. 92

Fig 92 Linsmayer's screw traction apparatus for the femur and lower leg with perineal support and screw for longitudinal traction.

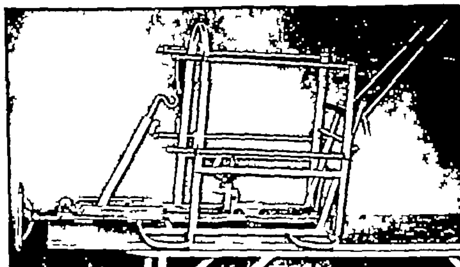


Fig 93

Fig 93 Linsmayer's screw traction apparatus for the lower leg The reduction frame is attached to the traction apparatus, also a sterilizable winch for the extraction of nails.

31 Hohmann bone-elevators (Fig 89)
32 Lambotte periosteal raspatories (Fig 90)
33 Strong Langenbeck bone hooks (Fig 91)
34 Bone-saws
35 A Demel or Kirschner wire tightener
36 An arm or leg skeleton

It is irresponsible to begin a medullary nailing operation without having these or similar apparatus and instruments available.

ad 1 Local anesthesia in fresh fractures has been discussed on page 60 L I/99, plexus anesthesia on page 62 E I/101 and spinal anesthesia on page 62 E I/102

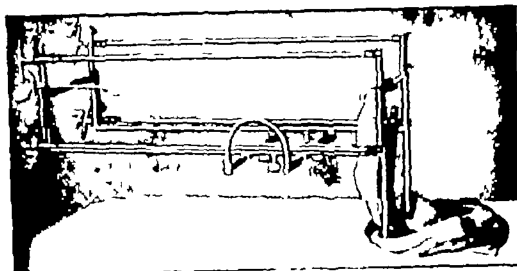


Fig 97

Fig 97 Böhler's screw traction apparatus for the humerus with reduction frame including the 4 rotating double bars with ratchet wheel ( ) and pawl attached

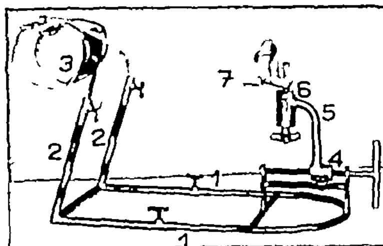


Fig 98

Fig 98. Böhler's screw traction apparatus for the forearm. To a telescoping base frame (1) 2 tubes (2) are attached obliquely at the proximal end a bar with a 15 cm trough (3) can be placed into either one of these oblique tubes. The trough is provided with 2 straps for holding the upper arm At the distal end, a screw (4) moves a vertical rod (5) with a universally adjustable ball-and-socket joint (6) The ball carries a wooden plate (7) with 3 cork wedges attached to it which are placed between the fingers. The hand is fastened to the wooden plate with a strap

tached to that for the upper arm that it permits use for various upper arm lengths To the rod for the upper arm is fastened the extension mechanism which again consists of an oblique upright attached to a traction screw Longitudinal traction is exerted by screw traction (Fig 94)

For lateral traction application is again made of the principle of the four rotating bars which are attached to two frames as wide as the length of the upper arm Bandages wrapped around these are tightened by turning these rods and thus traction and countertraction can be exerted in any desired direction (Fig 999)

Böhler's reduction apparatus Because it was very difficult to have new apparatus built due to lack of skilled craftsmen and material, I attached the four rotating bars devised by Linsmayer to my screw traction apparatus for arm and leg (Figs. 55a—58 E I, 71–76 and pages I/79, 80)

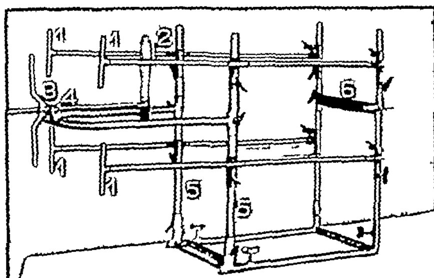


Fig. 95

Fig. 95 Bohler's screw traction apparatus with two sets of Linsmayer's double bars with ratchet wheel and pawl (1) The long screw is attached to the foot-plate (2) The wings of the nuts are shaped into two hand-grips, each 10 cm. long (3) to permit exertion of a sufficiently strong pull in femoral fractures or old fractures. A lock-nut (4) serves to lock the screw The top cross-bar of the original frame (5) is omitted for insertion of the Linsmayer double bars. The transverse rest-piece (6) is used for the support of the knee in fractures of the lower leg and of the perineum in fractures of the femur

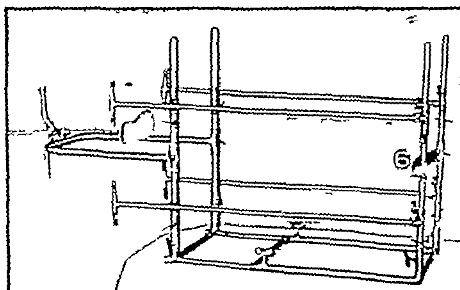


Fig. 96

Fig 96 Bohlers screw traction apparatus set up for fractures of the femur The necessary length has been obtained by elongating the base of the frame from its telescoped position shown above (Fig 95)

the trochanter of the injured leg upward The necessary length for traction can easily be obtained by reversing the oblique hook carrier on the traction screw thus increasing the distance between the hook and the perineal support (Fig 529)

For nailing of the humerus an apparatus has been constructed which is also based on the Böhler screw traction apparatus for the upper arm Again the original frame arrangement was abandoned in favor of a simple double right-angle rod The rod carrying the forearm is so at

ad 7 Each pair of rotating double rods is connected by two vertical rods If the vertical tubes of the screw traction apparatus for the upper arm are filed open, the rotating double rods can be placed upon them They are then used in the same way as on the lower leg or on the femur

If the rotating double rods are removed the apparatus can again be used for the reduction of para articular fractures of the lower leg and the humerus and for the application of a plaster cast under continuous traction

Figure 528 shows a fracture of the femur, Fig 804 a fracture of the lower leg and Fig 998 a fracture of the humerus reduced and secured in such a way that the fragments cannot slip during the nailing

The rods do not interfere with fluoroscopy in both planes For X ray pictures, the film holder can be placed above over the bandages instead of being held, thus avoiding exposure of the hands to radiation For the lateral views the film holder can be hung from the rods by means of hooks

For fluoroscopic control we are now working on a method of picture transmission to permit the operating surgeon continuous survey of the position of the fragments and of the nail throughout the operation without exposing himself to X ray radiation and without disturbing the sterility of the operative field

The *screw traction apparatus for the forearm* (Fig 98) serves for the reducing of forearm fractures With the ball joint under the hand it is possible to secure the wrist joint in any direction and to pronate and supinate the forearm Lateral traction is not always possible on the forearm because this would press the fragments against the interosseous space and cause an angulation

Wittmoser describes his reduction apparatus in 'Der Chirurg', No 2 1943, as follows

'The apparatus consists of reduction rings (3) dove-tail slides (9) and slide frame (4) (Fig 99)

By means of the reduction rings (3) forces transverse to the long axis of the fractured limb are exerted as needed in order to bring the fragments into contact. Each ring is mounted on a *slide track* (9) and can be moved into any position in the long axis of the *slide frame* (4) (It is best to apply one ring immediately proximal and the other immediately distal from the fracture) By means of the *hand cranks* (5 6) the reduction rings can be moved on the slide track vertically to the long axis One spindle (5) raises and lowers the ring the other spindle (6) moves it toward or away from the center of the frame Therefore each *reduction ring* can be moved in *every direction* transversely to the long axis of the apparatus—also therefore of the extremity Since the limb is encircled a *change of position* can be obtained in a few seconds by corresponding turns of the cranks The rings are *roentgenologically translucent* made of wood and can be opened to permit convenient placement of the limb The range of movement is such that they can pass each other completely It is thus possible to shear off the limb so to speak (Figs 100 101) In this way any lateral displacement as well as angulation can be corrected and over-corrected

'The three elements of construction *reduction rings* (3) *slide tracks* (9) with hand-cranks (5 6) and *slide frame* (4) together form the *reduction apparatus* proper In order to obtain apposition of the fragments it is first necessary to correct the shortening For this any one of the usual traction apparatus or fracture tables can be used The above apparatus is therefore merely a *supplemental accessory* to one of the commonly used *traction tables*

In order to be able to work independently of a traction apparatus a traction attachment was added to this apparatus For this purpose certain parts of the well known Böhler extension

Use of the apparatus for medullary nailing of the lower leg is shown in Figs. 95, 803 and 804, of fractures of the femur in Figs. 96, 527 and 528, and of fractures of the humerus in Figs 97 and 998

If the apparatus for the lower leg is pulled out, it can be extended to a length of 109 cm., whereas a normal leg measures only 75–87 cm on the inside Whoever uses my traction apparatus for the leg also needs the following for medullary nailing, as illustrated in Figs. 95, 96 and 685

1 Four rotating double rods with ratchet and pawl (1)
2 A new traction screw of 45 cm length with a foot plate (2)
3 A wing nut extended into hand grips (3)
4 A lock nut for locking the traction screw (4)
5 Two vertical rods instead of the large vertical U-shaped frame (5)
6 For fractures of the femur, a new slightly curved cross-piece of 3.5 cm diameter (6)
7 For the screw traction apparatus for the upper arm, the four rotating double rods with ratchet and pawl are also needed (7)

ad 1 With the 4 rotating double rods, lateral displacement can be corrected in all directions after the shortening has first been eliminated Traction and counter traction as needed can be exerted either in the frontal or in the sagittal plane Oblique traction can also be exerted if both ends of one bandage are fastened to one and the same double rod instead of to two different rods When the fluoroscope or X ray picture reveals good position of the fragments, it is best to use two more bandages to secure the position in the plane vertical to the one in which the other two bandages were applied. If, for instance the first set of bandages has been used in the frontal plane (Figs 528 and 804) this additional set of bandages should be used in the sagittal plane in this way any lateral displacement will be prevented while the nail is being driven in.

ad 2 The 45 cm. long traction screw can be used for lower leg fractures as well as for femur fractures The foot can be stabilized with the foot plate in such a way that the leg cannot sway while the nail is being driven Furthermore it provides an effective counter pressure during the driving of the nail so that the fragments do not separate while the nail is hammered into the distal fragment In order to prevent this longitudinal traction should be released in fractures of the femur as soon as the guide pin has entered the distal fragment and in fractures of the lower leg as soon as the nail has penetrated the distal fragment.

ad 3 The long handles of the wing nut permit the application of considerable force when exerting longitudinal traction

ad 4 With the lock nut the screw spindle as well as the foot plate can be fixed in any position.

ad 5 From the distal U frame of the original screw traction apparatus (Figs. 55a–57b E I/71–75) the cross-piece has been removed in order to permit the two rotating double rods to slide over it.

ad 6 The 3.5 cm thick curved cross-piece is padded and affords the necessary counter traction between the legs when longitudinal traction is applied

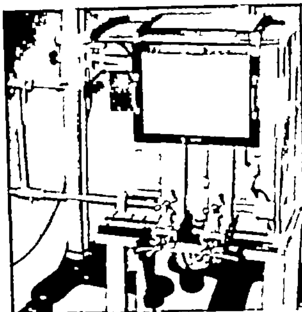


Fig 102

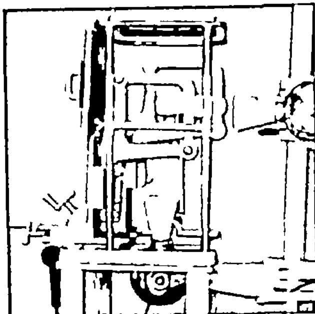


Fig 103

Figs. 102, 103 A rectangular metal frame is attached to the vertical rods (10) of figure 99 For fluoroscopy during reduction one screen can be placed above the other hung from the side Figure 103 shows also the position of the 2 X ray tubes

tion screw with a hand wheel (8) strong traction can be exerted on the foot plate (2) The foot plate is fastened to the sole of the foot (Figs 530 531 806) or to the forearm (Fig 1000)

The traction screw (1) can be used as a *pressure screw* as well Therefore by turning the hand wheel (8) in the opposite direction traction can be released and pressure can be exerted

This detail is important for avoiding a separation of the fragments which has so frequently been noticed in medullary nailings of the lower leg Böhler has emphasized again and again the importance of avoiding diastasis for the healing of fractures and therefore recommended strong impaction in nailing of hips Although the callus stimulating effect of the medullary nail[1] has led to bridging of rather large gaps we believe that we have noticed disturbances arising from a diastasis of fragments From these considerations the screw (7) was constructed in such a way that pressure can be exerted after the nail penetrates into the distal fragment With counter pressure from the foot plate it will now be possible to drive the nail in further without producing a separation of the fragments

This apparatus is constructed for the reduction of fractures of the femur lower leg and humerus (Figs 530 531 806 and 1000) and built strong enough to apply a force of more than 50 Kg in any direction

If a strong traction table is not available the traction accessory as described above is attached (Fig 99) The apparatus is best placed upon a small (50 × 70 cm) and low (70 cm) table with casters. This provides a convenient working level for the operation The table top contains *a window* the size of the frame In this window the lower X ray tube can be moved The patient is placed upon an operating table the foot section lowered and the apparatus is put in its place Of course the nailing may also be performed by using an ordinary firm table (Figs 102 103)

The *X ray tubes* are so arranged that one tube works from underneath the table the other at a right angle to it The latter is placed opposite that side from which the crank handles of the reduction rings are controlled When working in *bright* light the progress of the nailing can be followed with the hand fluoroscope or with X ray pictures in two planes

[1] In the meantime it unfortunately developed that the medullary nail does not stimulate the formation of callus, but retards it.

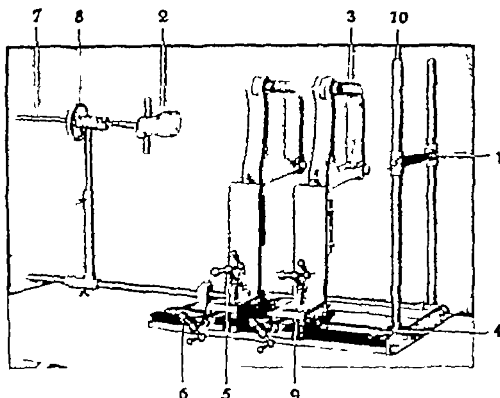


Fig. 99

Fig. 99 Wittmoser's reduction apparatus with traction bar attached. (1) Transverse rest-bar for the perineum (or for the popliteal space or the side of the chest) (2) Footplate (3) Pair of wooden reduction rings. (4) Frame with slide track for moving the reduction-ring assembly in a horizontal direction (5 6) Hand cranks for the screws which raise and lower (5) the rings or move them crosswise (6) (7) Screw for pulling or pushing on the foot. (8) Hand wheel (9) Dovetail slide. (10) Vertical rods.

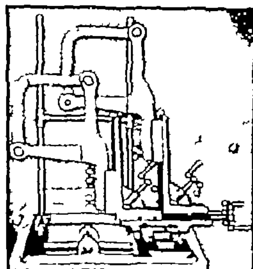


Fig 100

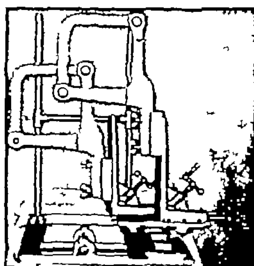


Fig 101

Figs. 100 101 These figures show how the 2 rings can be moved against each other

apparatus suitably modified were used (Fig 99) The cross bar (1) which can be adjusted in height on the vertical rods (10) serves as counter traction It rests against the perineum for fractures of the femur against the popliteal space for fractures of the lower leg or against the lateral chest wall for fractures of the humerus (Figs 530 531 806 and 1000) By means of a trac

ad 11 *Rapid development** If several X-ray pictures are necessary in difficult cases, the usual method of developing would require a waiting period of 8–10 minutes for each picture. If the *rapid developer* is used, the pictures can be inspected after 2–3 minutes. We are using a method given us by the Agfa Company. The formula is as follows:

Developer			
	Solution I	Water	500 c.c.
		Pyrocatechol	50 grams
		Sodium sulfite cryst	100 grams
	Solution II	Water,	500 c.c.
		Sodium hydroxide	30 grams
		Potassium bromide, cryst	50 grams

According to Mr. Lster, our photographer, the procedure is as follows. Both solutions are prepared in boiling water. Equal parts of each are mixed immediately before use since the mixture can be used for only about 1 hour. After use it must be discarded. Developing time is about 50–60 seconds. Linen and hands must be protected, therefore the film should be handled with clips to prevent damage to the skin. After development, short rinsing in clean water. The film is then placed for 2 minutes into a fixing solution.

Fixer		
	Water	1 liter
	Sodium thiosulfate	300 grams
	Potassium metabisulfite	30 grams

For better keeping quality it is advisable to return the pictures to the fixing solution for another 10 minutes after they have been inspected. This should then be followed by a thorough washing for 2 hours.

The pictures may be inspected in daylight after one half minute in the fixing solution; this however, causes hypo-spots and yellow fog which greatly impair the quality of the X-ray pictures.

ad 12 In fractures below the middle of the femur or tibia the elimination of angulation before the introduction of the guide wire is very important. In order to determine it, a celluloid *protractor rule* (Fig. I 57) is necessary.

ad 13 Before medullary nailing is undertaken it must be ascertained whether *medullary nails* of proper length and size for this particular case are on hand. The operation should not have to be interrupted because proper size nails were not

* The same results as described under this heading can probably be obtained with fresh commercial developers, with a normal developing time of 3 minutes at 68°F (20°C), if used at a higher temperature (about 7?°F, 25°C) for about 1 minute, using high speed films and good intensifying screens. With a similar type of fresh commercial fixing solution at the same elevated temperature the films might be ready for inspection after ½ minute of fixation and completely fixed in 1 minute. The rinse water and final wash water must be at the same temperature as the developer and fixer. Since the higher temperatures make the emulsion more vulnerable to mechanical injuries, precautions against rubbing and scratching the films must be taken as with the pyrocatechol-sodium hydroxide technique. The latter however will most likely be found more injurious to the skin than the commercial developers with which the precautions as to the hands are probably unnecessary (except for workers allergic to certain photographic chemicals). Experimenting along these lines with commercially available solutions and brands of film will be necessary for satisfactory results, but the efficiency of the screens must also be taken into consideration. (H. T.)

In contrast to this however, working in a *darkened room* with fluoroscopic screens has several advantages On the vertical rods (10) a suitable frame is placed to which 2 fluoroscopic screens are attached at right angles to each other With a diaphragm, the radiation is reduced to a narrow bundle so that the entire direct radiation is absorbed by the lead glass of the fluoroscopic screen This completely protects the operating surgeon and assistants from direct radiation. Above all, however the operator can follow the course of the reduction the penetration of the guide wire and of the nail directly on the fluoroscopic screen Thus the surgeon becomes independent of the description by the fluoroscoping assistant and can perform the operation more quickly and effectively

The switches for the X ray tubes can be placed on the side of the crank handles (5 6) so that one person can control the reduction rings as well as the X ray apparatus from one place One can soon get used to performing all this in the dark, using lead gloves for protection against secondary radiation.

When working in a darkened room the surgeon can himself during operation perform the reduction by manipulating the crank handles after they have been covered with sterile towels. This makes him largely independent of experienced assistants, a fact which is of importance especially for smaller hospitals

Advantages of this apparatus

"I By means of the reduction rings and the hand cranks it is possible to reduce the fragments *quickly* and *very accurately* They are *firmly retained* in this position

II. Reduction is possible *in every direction* vertical to the long axis.

III The ring shape of the reduction unit permit *a rapid change in the direction of the reducing forces* by appropriate manipulation of the hand cranks *without changing anything* on the apparatus.

IV The hands of the manipulating physician are not exposed to the X rays

V X ray damage to the patient and the physician can be avoided by shortening the fluoroscopic time by the use of stable fluoroscopic screens with lead glass or by substituting control films for fluoroscopy

VI The hand cranks (5 6) can be manipulated in the dark with lead gloves. The X ray tubes can be activated from the same place.

"VII. After covering the cranks with sterile towels the surgeon can personally correct the position during the operation and can himself thus observe the progress of the nail on the fluoroscopic screen

VIII The apparatus (3 4 9) can be placed upon one of the usual traction tables and can be considered an accessory to the same for medullary nailing purposes.

IX. By constructing the traction screw as a pressure screw as well, it is possible to use the foot plate for counter-pressure to avoid diastasis."

ad 6 *Two mobile X ray units* (Figs 103 528, 804 998, 1098) are indispensable. Without fluoroscopy closed medullary nailing is absolutely impossible With only one X ray apparatus the necessary frequent change of position for anteroposterior and lateral fluoroscopy consumes so much time that the procedure may under difficult circumstances become unbearable for the patient.

ad 7 One *fluoroscopic screen* is always essential when working in a darkened room If two are available the operation can be performed more quickly (Fig 103)

ad 8 If the operation is performed in bright light a *hand fluoroscope* (Figs. 104–107) is needed The model of Heinz Braun (Figs 105, 107) has proven particularly helpful because the fluoroscopist is not in the path of the radiation and because it is counter balanced.

ad 9–10 *Lead apron* and *lead gloves* must be used by the fluoroscopist to avoid serious radiation damage if medullary nailings are performed frequently

the skin A recess of 2 cm depth will prevent driving the nail too deep into the femur

ad 20 The *hack saw* (Fig 70) serves for sawing off nails which can neither be driven forward nor extracted

ad 21–23 The *extractors for medullary nails* of Küntscher, Stör and Pohl (Figs 71 and 83) serve for the extraction of nails that have taken a false course, that cannot be driven further or that are to be removed completely

ad 24 The *forceps* of Jörg Böhler (Fig 84) serves to firmly hold the hook which frequently slips out of the eye of the nail during extraction

ad 27–35 The use of these is evident from Figs 85–91



Fig 106



Fig 107

Fig. 106 Ordinary hand fluoroscope in use

Fig. 107 Operation fluoroscope of Heinz Braun in use

X ray Technique in Medullary Nailing

Good X ray pictures are absolutely essential for determining the indication for medullary nailing for determining the width of the medullary canal for the nailing itself and for the subsequent observation The rules given on pages I/59–72 for centering the films for the position of the fracture on the film, for the frequency of control pictures and their labeling should be observed Whoever is not capable of educating his personnel accordingly, will for these reasons alone experience many failures and is in my opinion not entitled to undertake medullary nailing

X ray pictures of fresh fractures must be made under *local anesthesia* in order to be able to position the limb properly for the lateral views

For operations which are likely to last some length of time and will require several X ray pictures a *rapid developer* (see page 35) must be used. This shortens the procedure greatly because the films can be inspected after 2–3 minutes instead of 10 minutes

Prevention of Radiation Damage in Medullary Nailing

Without proper reduction apparatus (Figs 92–103, 527–531 803–806, 998–1000, 1098–1100) the exact reduction and retention of the fragments during medullary

or hand nor should later complications develop because the nail used was either too thick or too thin, too short or too long (Figs 194–251)

The medullary nails for the femur and the forearm are straight (Figs 67, 69) In those for the femur the guide groove is shaped in such a way that it cannot slip off the guide pins The nails for the humerus and lower leg are usually double. Their tips are slightly bent upward because they are introduced into the bone from the side (Fig 68) The tip is rounded off in all nails so that they will not injure nerves or blood vessels in case they slip out through the bone or at the fracture site. In addition to this, they are slightly conical for better driving and extraction.

ad 14 The *guide pin* (Fig 81) serves in the femur for threading the fragments. Especially in fractures below the middle it must not be introduced until after all angulations have been completely corrected, otherwise the medullary nail will permanently retain the incorrect position On the tibia and on the humerus the

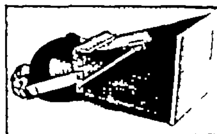


Fig 104



Fig 105

Fig 104. Ordinary hand fluoroscope. This must be held with one hand and must be removed when not in use (Fig. 106)

Fig 105 Operation fluoroscope of Heinz Braun. During operating and reducing, one may look through the tinted goggles below without removing the fluoroscope. The head piece is counterbalanced by a weight behind therefore it need not be held, leaving both hands free. The screen is attached obliquely so that the radiation does not strike the head and eyes of the operator Furthermore, the screen can be rotated.

guide pin is used as a rule only for measuring the size of the medullary canal and for determining the length of the nail.

Since the resistance met in the bone is frequently quite great a *strong handle* for the guide pin is very important (Fig 82)

ad 15 The *awl* (Figs 72 73) serves on the tibia, on the humerus on the ulna and on the radius for piercing the bone for the insertion of the medullary nail It also serves for opening the medullary canal in pseudarthrosis.

ad 16–17 The *hand drill* (Fig 78) or better an electric drill (Figs. 87–89 E I/104–106) with round burr serves for drilling the hard compact bone of the humerus or the tibia if the medullary nail is inserted from distally and for opening the sclerosed bone ends in cases of pseudarthrosis

ad 18 The *hammer* (Fig 74) must be of the necessary weight so that the medullary nail, especially on the femur can be driven with the required force

ad 19 The *driving punch* (Fig 75) serves for driving the nail if the end approaches

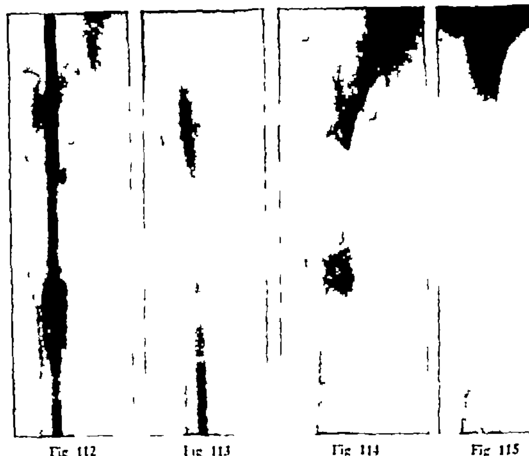
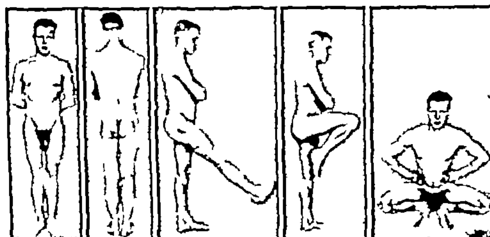


Fig 112 Fig 113 Fig 114 Fig 115

November 27 1942 April 16, 1943

Figs. 112 113 Same as Figs 108–111 after 8 weeks. Bony union in good position. Good, but not excessive callus formation All joints entirely free. Resumes his previous work.

Figs. 114 115 Same as Figs 108–111 after 6½ months immediately after extraction of the nail, ambulatory under local anesthesia. Position excellent. The fracture line is completely obliterated. Uniform thickening of the bone at the fracture site



Figs. 116–120

November 27 1942

Figs 116–120 Same as Figs 108–115 eight weeks after the accident. Muscles strong All joints show normal range of active motion. Ten weeks after the fracture he went through strenuous training without discomfort. During a 10-day furlough, the nail was extracted and he was then inducted into the army

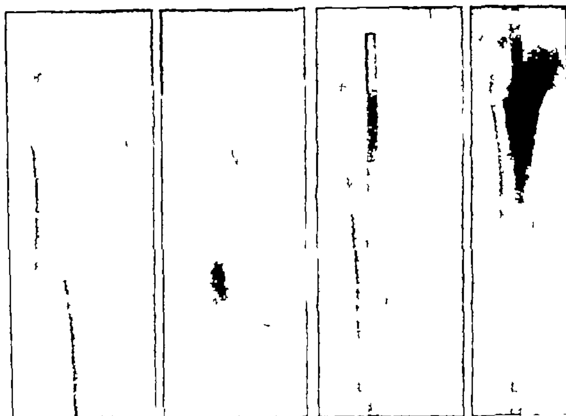


Fig 108 Fig 109 Fig. 110 Fig 111

October 3 1942 October 3, 1942

Figs. 108, 109 Transverse (sheared) fracture of the femur between middle and proximal third, in a 17 year old roofer who was struck by a truck while riding his bicycle. The distal fragment is displaced medially by full shaft s thickness and posteriorly by more than twice the thickness of the shaft.

Figs. 110 111 Same as Figs 108 109 immediately after medullary nailing under spinal anesthesia After adequate impaction (see Figs 534–537) the fragments are in accurate apposition Got up on the 4th day without bandage and left the hospital on the 20th day

nailing may be extremely difficult A W Fischer reports of hour long 'wrestling matches with the fragments and one can frequently hear of such lengthy operations Frequent and prolonged fluoroscopic exposures particularly endanger the hands of the fluoroscopic assistant, especially if many medullary nailing operations are performed The danger for the patient is less A W Fischer reported a third degree burn caused by the X rays

Protection of the patient To avoid X ray damage to the patient s skin the X ray tube must not be brought too close to the skin (see page II/908) as a rule not closer than 30 cm

Protection for the physicians The fluoroscopic assistant must not work without *lead gloves* and *lead apron* otherwise serious X ray burns will occur Overly zealous young physicians do not want to believe in these radiation damages so common in older roentgenologists and orthopaedic surgeons.

Reduction must never be performed with the hands under the fluoroscope For this reason I prohibited medullary nailing until suitable *reduction apparatus* became available with which it was possible to correct lateral displacements and angulations

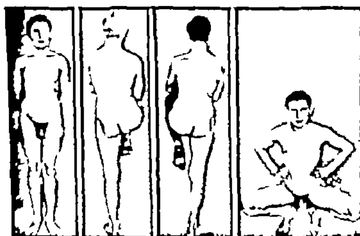


Fig. 125 Fig. 126 Fig. 127 Fig. 128

November 13 1941 December 17 1941

Figs. 125, 126. Same as Figs. 121–124. After 8 weeks. Good callus formation laterally and posteriorly but fracture line still visible medially and anteriorly as in Figs. 139–142 E, I/218–221. Epiphyseal line slightly decalcified.

Figs. 127, 128. Same as Figs. 121–124 after 3 months and 2 weeks after extraction of the nail. Fracture line obliterated. A trace of the fracture line still shows within the callus on the medial side. Varus angulation of 5° because the nail was removed too soon. (see Figs. II/242–245.) This type of fracture should not be nailed.



Figs. 129–132

November 13 1941

Figs. 129–132. Same as Figs. 121–128 8 weeks after fracture of the tibia. All joints show normal range of active motion. No muscle atrophy. Resumed his previous work after 8 weeks. Without nailing the healing of this case would not have taken much longer. The same result could have been obtained in a safer and simpler way by a plaster cast without nailing.

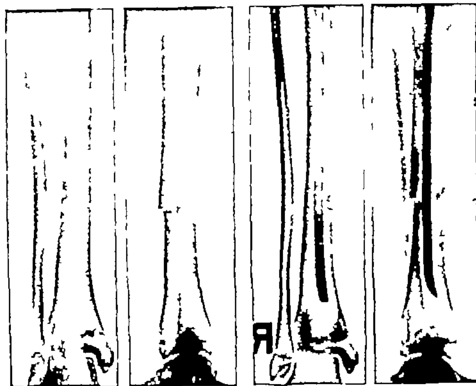


Fig 121 Fig. 122 Fig 123 Fig 124

September 17 1941 September 17 1941

Figs. 121 122 Slightly oblique leverage fracture of the tibia below the middle in a 15-year-old helper who was run over by a wagon. Valgus 5° recurvation 7–8°

Figs. 123 124 Same as Figs 121 and 122 after medullary nailing under local anaesthesia and a short ethyl-chloride analgesia. The nail is too short. The valgus position persists. Recurvation is corrected. Because of a simultaneous injury to the other leg he did not get up until the 20th day Left the hospital on the 24th day without bandage. We no longer use nailing in this type of fracture.

without touching the fragments Unless the fragments are secured by lateral traction straps even if they are in good position by longitudinal traction, they will slip off (as we have experienced repeatedly) during the concussion caused by the hammer blows while driving the nail and will have to be reduced again and again

For fluoroscopy the *operating fluoroscope* of Heinz Braun (Figs 105 107) is especially adapted because the user is not exposed to direct radiation

Projection of the fluoroscopic image The ideal goal would be reached if we could project the biplane fluoroscopic images onto a screen on the wall during the reduction, the introduction of the guide wire and the nailing This would be particularly helpful in teaching The necessary strong light sources are not yet available for this purpose. We must be satisfied for the time being with as short fluoroscopic exposures as possible (1 to 2 seconds) With sufficient experience it is possible to gain a satisfactory impression during this short period

Determination of the Width and Length of the Medullary Canal

Before the operation is undertaken the width of the isthmus of the medullary canal, the exact length of the bone and the conditions of the cancellous structure at the ends must be known These can be determined by correctly focused X ray



Fig 138 November 15 1941 — Fig 139, Fig 140 April 8 1942 — Fig 141, Fig 142 March 8 1943

Fig 138 Double fracture of the right tibia with intermediate fragment of [illegible] cm length and single fracture of the fibula Simultaneous double fracture of the right femur (Fig 133)

Figs 139 140 Same as Fig 138 after 5 months Good callus formation on the lateral aspect of both fractures whereas on the medial surface the fracture line still shows Got up without bandage 4 weeks after medullary nailing of the femur and lower leg

Figs. 141 142. Same as Figs. 138–140 18 months after injury and 8 months after extraction of the nail Both fractures show bony consolidation Slight varus angulation and antecurvation

the operation by the use of too thick a nail (Figs 153–160 and 194–197) or later if too thin or too short a nail is used, giving insufficient stability This may cause angulation (Figs 202–212) rotation (Figs 222 231), or even re fracture of the bone at another site (see page 87)

If the nail is too long it may penetrate into the joint either during the operation (Figs 213–221) or later (Figs 894–901) and cause serious disturbances

For exact determination of the length of the nail in fractures close to a joint, a guide wire must be used for measuring (Figs. 707 708 811 876 877)

Time for Closed Medullary Nailing

Fresh *closed* fractures can best be reduced within the first hours, as long as no hematoma or no swelling has developed It is absolutely essential, however, that *no shock condition* be present Since the operation is not an emergency it may be delayed for several days if no particular swelling develops and no tension blebs form Otherwise one must wait until the swelling subsides, i e about 8–10 days During this period a pin or wire traction is used for fractures of the femur or lower leg (see

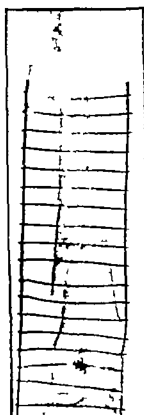
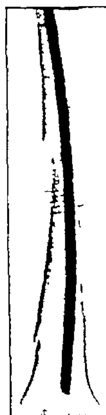
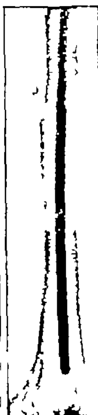






Fig 133 — November 15 1941; Fig 134, Fig 135 — January 3 1942; Fig 136, Fig 137 — March 8, 1943

Fig. 133 Double fracture of the right femur with an intermediate piece 20 cm. long, also double fracture of the right lower leg (Fig 138) In a 28-year-old physician whose automobile ran out of control and struck a tree. At first tibial traction with 10 Kg and calcaneal traction with 3 Kg. On November 28, padded plaster cast for transportation. On December 3 spinal anesthesia and medullary nailing, first of the lower leg in a screw traction apparatus (Fig. 803) then of the femur in a screw traction apparatus (Fig 527) Elevation on Braun leg-frame.

Figs. 134 135 Same as Fig 133 one month after medullary nailing. Valgus and recurvation of 5° each at the proximal fracture. Good position of the fragments at the distal fracture. Good callus formation Gets up without bandage.

Figs. 136, 137 Same as Figs. 133–135 18 months after injury and 8 months after removal of the nail. Both fractures healed in good position Resumed his full activities as a surgeon 5 months after injury Initially one-third restriction of the ankle joint, all other joints actively free. No discomfort in walking or standing

pictures taken in exactly antero-posterior and lateral directions If a uniform focus-film distance of 80 cm is used allowance must be made for the enlarged projection of the bone due to bone film distance and 2 mm must be deducted from the measurements of the femoral cavity on the film from the other bones about 1 mm. The conditions of the medullary cavities are shown in Figs 1–66 It has been proposed to place a medullary nail on the film alongside the extremity as the picture is taken This will lead to erroneous conclusions because the nail is closer to the film than the bone Pictures which might be used for measurements could possibly be obtained by fastening the nail perhaps with adhesive plaster to the limb in such a way that it occupies the same distance from the film as the bone.

If exact measurements are omitted difficulties may arise immediately during



Fig 147 Fig 148 Fig 149 Fig 150 Fig 151 Fig 152

November 6 1942 January 20 1943 May 10 1943

Figs 147 148. Same as Figs. 143–146, after 5 weeks Wounds healed without complication The angulations were corrected but a 10° antecurvation was produced from a 15 recurvation Nail markedly bent at the level of the fracture The leg was straightened again

Figs. 149 150 Same as Figs 143–146 after 4 months Good alignment in both views Vigorous callus formation laterally and posteriorly as in Figs 139–142 E, I/218–221 Painless gait.

Figs. 151 152. Same as Figs 143–146 6 months after injury on the day of extraction of the nail. Bony union of both bones in good position Still trace of fracture line medially and anteriorly All joints actively free

become necessary if the spinal anesthetic does not work or if the operation becomes prolonged complications which can never be foreseen

Positioning for Medullary Nailing Without Exposure of the Fracture Field

Fractures of the femur are placed on the well side with marked flexion of the hip of the well leg and slight flexion of the hip of the injured leg because in this position the tip of the greater trochanter is best accessible (Figs 527–531)

Fractures of the lower leg are secured in recumbent position with right angle flexion at the hip and at the knee joint (Figs 803–806)

Humerus fractures are placed upon the screw traction apparatus in mid position of all joints (Figs 998–1000)

The position for *forearm fractures* is evident from Figs 1098–1100

Reduction of Fragments for Medullary Nailing Without Exposure of the Fracture Field

By positioning the patient upon the reduction apparatus (Figs 527–531, 803–806, 998–1000 and 1098–1100) the rotatory displacement between the fragments is



Fig 143 Fig 144 Fig 145 Fig 146

September 30 1942 September 30, 1942

Figs. 143 144 Compound leverage fracture of the right lower leg below the middle in a 40-year-old helper who was struck by a cable drum Shortening, lateral displacement and marked angulation. Small wedge fragment antero-laterally Wound excision and medullary nailing

Figs. 145 146 Same as Figs. 143 144 The nail is somewhat too short. Shortening and lateral displacement are corrected. Varus angulation of 10° and recurvation of 15° persist. We no longer nail this type of fracture because the operation is very dangerous.

Figs. 684 E II/1604–1607 and 841 E, II/2374) Humerus and forearm fractures are immobilized with a suitable splint.

As long as marked swelling and blister formation prevail or as long as there are deep abrasions or larger wounds on other parts of the body, the operation must not be performed because infection might occur

Anesthesia

Fresh *closed* fractures can usually be treated under the same local anesthesia which was applied for the taking of the X ray pictures Additional local anesthesia is needed for the site where the nail is inserted For the nailing itself a short general analgesia is sometimes necessary

If the operation is performed after 8–10 days the fracture is anesthetized locally for the positioning and for the reduction In general however the best procedure is to use spinal anesthesia for the leg and plexus anesthesia for the arm (see pages I/101, 102)

If spinal anesthesia is used no preliminary medication (narcotic) should be given which might interfere with a subsequent general anesthesia. The latter may

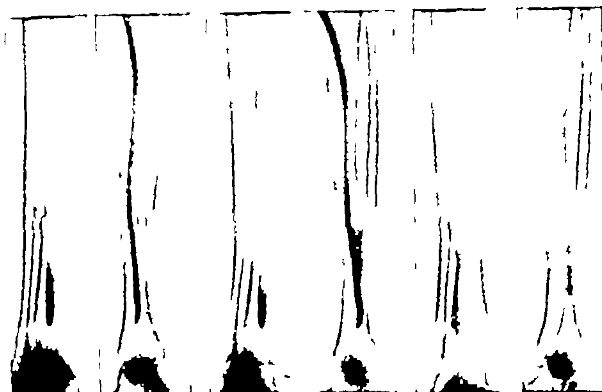


Fig 147 Fig 148 Fig 149 Fig 150 Fig 151 Fig 152

November 6 1942 January 20 1943 May 10 1943

Figs 147 148 Same as Figs 143 146, after 5 weeks Wound healed without complication The angulations were corrected but a 10° antecurvation was produced from a 15° recurvation Nail markedly bent at the level of the fracture The leg was straightened again

Figs 149 150 Same as Figs 143 146 after 4 months Good alignment in both views. Vigorous callus formation laterally and posteriorly as in Figs 139–142 I, I/218–221 Painless gait.

Figs 151 152. Same as Figs 143 146 7 months after injury on the day of extraction of the nail. Bony union of both bones in good position Still trace of fracture line medially and anteriorly All joints actively free

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Reduction of Fragments for Medullary Nailing Without Exposure of the Fracture Field

By positioning the patient upon the reduction apparatus (Figs 527–531 803–806 998–1000 and 1098–1100), the rotatory displacement between the fragments is



Fig 153 Fig. 154 Fig. 155 Fig. 156
November 6 1941 November 6, 1941

Figs. 153 154. Oblique fracture of tibia and fibula proximal from the middle in a 33-year-old working woman from slipping

Figs. 155 156. Same as Figs. 153 154 after medullary nailing under local anesthesia The nail is too thick therefore it could not be driven further and had to be cut off with the hack-saw Valgus 8° recurvation 12° Therefore, gaping of the fracture line medially and posteriorly We no longer nail fractures of the lower leg, because the old methods are simpler and less dangerous.

eliminated By longitudinal traction with the screw lashed to the foot, arm or hand, the shortening and by lateral traction straps, the lateral displacement is corrected The entire procedure is controlled continuously by short repeated fluoroscopic views using two X ray machines In fractures distal from the middle of the humerus or of the lower leg final X ray pictures are taken in both planes in order to ensure that all angulations have been completely eliminated. In transverse fractures it is sometimes not possible to correct the lateral displacement in this way The longitudinal traction must then be removed the fragments angulated to a right angle against each other as shown in Figs I, 16–18 (toggling) In this way it is frequently possible to obtain complete apposition

Insertion of the Guide Pin and Driving of the Nail

When the fragments show good apposition and are firmly secured by lateral traction straps a short transverse incision is made about 2–3 cm long proximal from the greater trochanter medial from the tibial tuberosity above the olecranon behind the olecranon or on the dorsal surface of the distal end of the radius, and the guide pin is inserted again under fluoroscopic control in two planes As soon as it enters the other fragment it is pushed toward the opposite end of the bone In fractures distal from the middle it must reach to within 1 cm of the joint and in fractures of the humerus at all times to within 1 cm of the joint Then the required length of the nail is taken from the measurement of the guide pin

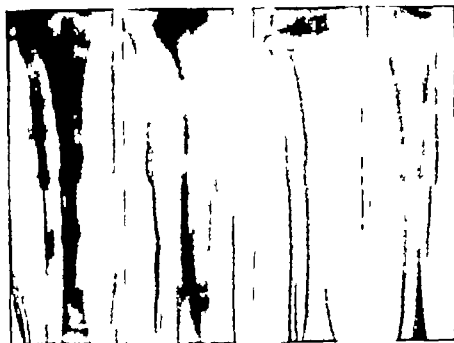


Fig. 157 Fig. 158 Fig. 159 Fig. 160

November 2, 1941 May 5, 1942

Figs. 157, 158. Same as Figs. 155, 156, after straightening the leg and application of a circular plaster cast from the ankle to the hip. Good alignment in both views. The gaping has disappeared. The bend in the nail at the fracture level is plainly visible. Left the hospital after 4 weeks. Cast was removed after 6 weeks. Figs. 159, 160. Same as Figs. 155, 156, after 6 months. Bony union in very good position. Good consolidation. All joints free. Walking endurance still somewhat restricted.

As soon as the guide pin is in exact position, a suitable nail is inserted. X-ray pictures in both planes are then absolutely essential to determine the location of the nail and the position of the fragments.

Straightening and Impacting of Fragments

Since the medullary nail has to be inserted on the tibia, on the humerus and on the radius from one side, frequently an angulation is noted in the X-ray pictures after the nailing is completed, viz. a re-curvation on the tibia and an ante-curvation on the upper arm. It is usually quite easy to straighten the bone (Figs. 143–160) over a padded wooden wedge (Fig. 952 I, II, 2816) or with a Phelps-Gocht osteoclast (Figs. 91 F, I/108). In Figs. 148 and 158 one can see how the medullary nail has been bent forward at the fracture site. Figure 158 shows how the fracture surfaces which were widely separated posteriorly have come into good apposition.

On the femur the bending of the medullary nail is difficult because it is too strong (Figs. 416–423). Usually in trying to bend the femoral nail one will only crush the cancellous bone.

Impaction of the fragments. If the fragments are not in apposition after correction of the angulation, they must be approximated into intimate contact by blows with the palm of the hand upon the sole of the foot, upon the knee, or upon the flexed elbow (Figs. 534–537 and 809–813); otherwise callus formation will be delayed or a pseudarthrosis may develop.

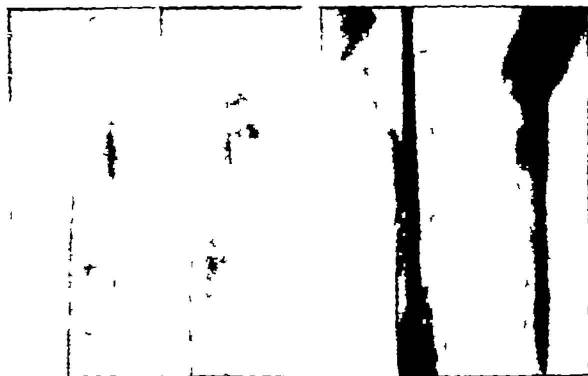


Fig. [illegible] Fig. [illegible] Fig. [illegible] Fig. [illegible]

November 2[illegible], 1941 November 21, 1941

Figs. [illegible] High spiral fracture of the left femur in a 5[illegible]-year-old man who was knocked down by a [illegible] cyclist. Paget's disease. [illegible]

Figs. 163–[illegible]4. Same as Figs. [illegible] after medullary nailing. The nail was too short and too thin (see Figs. [illegible]). [illegible] traction in [illegible]. [illegible] weeks.

Supplementary External or Internal Supports after Medullary Nailing

Transverse and short oblique fractures of the femur and tibia proximal to the isthmus of the canal which were reduced perfectly with a nail of sufficient length and thickness as shown in Figs. 108–120 and 540–55[illegible], can begin weight-bearing without additional external support after two weeks, as is the case with properly nailed hip fractures. Humerus fractures provided with a nail of proper length as shown in Figs. 1001–1005 need no plaster cast, traction or airplane splint.

Additional continuous traction. Spiral fractures of the femur in the proximal third with a long third spiral butterfly fragment (Figs. 161–168) cannot be maintained in good position with the medullary nail alone. The muscle pull and the position on Braun leg frame usually cause a gradual overlapping of the fragments and thus a shortening and angulation even if the nail was of sufficient length and sufficient thickness. These fractures must therefore be treated with additional continuous skeletal traction by wire or pin. If the nail is too short as in Figs. 582–589 it provides no fixation whatever in spiral fractures with a long butterfly fragment. These types of fractures should never be nailed, but treated with continuous traction.

Also transverse fractures immediately distal from the greater trochanter (above the minor trochanter) (Figs. 55[illegible]–569) require additional continuous traction to

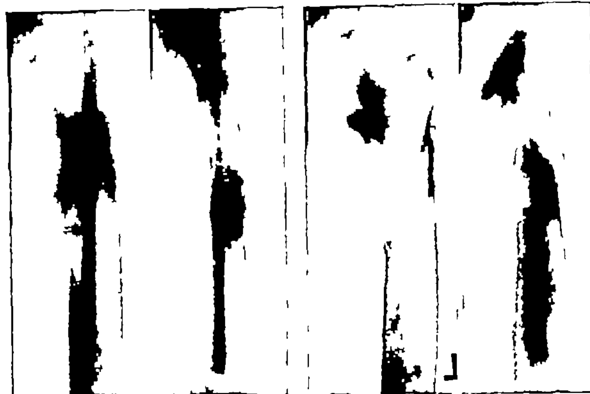


Fig 165 Fig 166 Fig 167 Fig 168

April 23 1942 February 22 1943

Figs. 165 166 Same as Figs 161–164 after 5 months. When shortening and angulation developed after 14 days, tibial traction with 9 kg was instituted This corrected the malposition Traction was removed after 4 weeks whereupon shortening of 3 cm. and varus of 5 and antecurvation of 20 recurred Callus fuzzy It cannot be determined whether this represents a globular callus from defective immobilization or periosteal appositions due to tables. Probably both contributed.

Figs 167 168 Same as Figs. 161–164 after 15 months. Good consolidation of the fracture with the same displacements as on April 23 1942 Shortening of 3 cm Limping gait Knee 160–175° as before the accident. Other joints free Such spiral fractures should not be nailed, but treated with continuous traction.

prevent angulation (Figs 562–569) Without continuous traction angulation will produce a coxa vara even if the nail used was of the proper thickness and length (Fig 560) Therefore as a rule no purpose is served by nailing such fractures. Fragmented fractures of the shaft however are eminently suited for nailing (Figs. 574–581 and 649–656) but without additional continuous traction skeletal at first and later skin traction shortening would occur

In comminuted fractures (as shown in Figs. 618–638) marked shortening can only be prevented by additional continuous traction

Supplementary Plaster Cast In all forearm fractures treated with short nails a plaster cast from the interdigital folds to the shoulder (Figs I 913–915) must be used because these nails do not protect the ulna or the radius against rotational strains This cast must be applied and split immediately after the operation

Fresh humerus fractures with too short a nail (Figs 1012–1015) are placed on an abduction splint

Fractures of the tibia distal from the middle require if the nail is too thin and

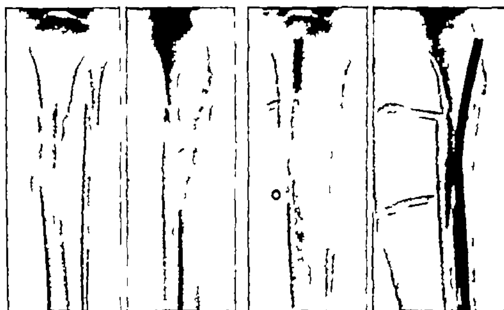


Fig 169 Fig 170 Fig 171 Fig 172

November 27 1941 November 27 1941

Figs. 169 170 Compound comminuted fracture of the left leg in a 36-year-old cleaning woman from explosion of a stove and burying by debris.

Figs. 171 172. Same as Figs. 169 170. After wound excision medullary nailing and application of an unpadded plaster cast which was split and fenestrated immediately Good position in both views. Two rubber drains are seen in the lateral view

too short in every case an additional walking cast (Figs 843 E, II/2414b and 880, 881 E, II/2650–2651) when they start weight bearing otherwise angulation and shortening will develop (Figs. 202–212) A short plaster cuff (Figs 205–206) can never prevent angulation in fractures distal from the middle In fractures of the proximal third, however (Figs 244–251) a plaster cuff from the hip to the ankle (Figs. 725–727 E II/2175–2177) can definitely prevent angulation In fractures below the middle of the tibia it is advisable to use a walking cast for initial weight bearing even if the nail is well anchored (Figs 836–843) It is best to exclude these fractures from medullary nailing

After medullary nailing of pseudarthroses of the lower leg a walking cast reaching to the hip must be applied (Figs 922–975)

After medullary nailing of fresh fractures of the femur a plaster cast is only necessary if the nail is too short since otherwise angulation will develop (Figs 390–403)

In summarizing it is evident that supplementary fixation is required only if unsuited fractures are nailed or if in fractures suited for nailing an unsuitable nail, either too thin or too short is used

Positioning of the Injured Limb after Medullary Nailing

Femur and leg fractures are best placed post-operatively upon a Braun leg frame The foot is suspended with a triangular sling (Fig II 2641) to prevent external rotation In order to recognize rotation (Figs 227–231) quickly it is necessary that the leg frame be kept horizontal. This requires a firm bed (fracture boards under



Fig. 173 March 4, 1942 — Fig. 174 March 31, 1942 — Fig. 175, Fig. 176 October 5, 1942 — Fig. 177, Fig. 178 March 12, 1943

Fig. 173. Same as Figs. 169–172 after 3 months. After removal of the cast a varus angulation of 15° developed. Fractures with such a short proximal fragment must not be nailed because the nail cannot provide sufficient stability and furthermore because it was both compound and comminuted. Without nailing this fracture would probably have united in 3 months.

Fig. 174. Same as Fig. 173 after correction of angulation and the application of another plaster cast. On the medial side the arrow points to the cut in the plaster cast by means of which the last 5° of angulation were corrected.

Figs. 175, 176. Same as Figs. 169–172, after 10 months. Union in good position

Figs. 177, 178. Same as Figs. 169–172 after extraction of the nail 15 months after the accident. The greater part of the fracture shows bony consolidation

mattress Figs. 53 E, I/65 and 70 L, I/91) In soft beds the frame slants in the long as well as the transverse axis of the bed and thus torsion can easily be overlooked

For *humerus fractures* only a sling or triangle cloth is necessary after operation provided the nail is well anchored (Figs 1002 1003) If the nail is too short the arm is placed on an abduction splint

Forearm fractures are elevated on a pillow following operation Only if marked swelling occurs need they be placed on an abduction splint for a few days

Functional Treatment after Medullary Nailing

In *fractures of the femur* the toes and the ankle joint must be exercised actively from the first day on Active movements of the knee and hip must not be started before one week, after the swelling and hematoma have receded If these joints are moved from the first day as many authors recommend pain develops the limb becomes hot and the swelling recedes much more slowly Even inflammation may set in It must be emphasized again and again that the knee joint will never suffer damage from one week s immobilization it will, however, suffer from too early motion

In *lower leg fractures* the toes must be exercised actively throughout the full range of motion from the first day on the ankle joint, knee and hip should not be actively exercised before one week has elapsed

In *humerus fractures* the wrist and forearm must be exercised actively through the full range from the first day on, the elbow joint and shoulder after one week

In *forearm fractures* the fingers and the shoulder must be actively exercised from the first day on the wrist and elbow joint after one week

General Symptoms following Medullary Nailing

Fever During the first week after nailing a slight rise of temperature to 37.5–38°C is common Such temperature elevations are, however frequently found in the wake of fractures without medullary nailing

Sedimentation rate of the red blood cells Dr Emilie Mayer at the suggestion of Dr Güttner examined the sedimentation rate in 53 cases before operation, after operation and during the entire healing period until the removal of the nail The rate always increased after nailing but not more than with other treatment methods and usually returned to normal values within one week After removal of the nail a marked increase in the sedimentation rate follows in femur fractures a lesser increase in other fractures (Fig 179)

Eosinophilia and reduction of hemoglobin content following medullary nailing Raisch reports the case of a 22 year-old female who developed an eosinophilia of 9 per cent following medullary nailing of a pseudarthrosis of the femur this disappeared gradually but not until after the removal of the nail six months later Otherwise the differential blood count showed no pathologic values, in particular no shift to the left. Such changes have so far been observed only in children, not in adults

In the case of Raisch, the hemoglobin before operation was 85 per cent, from the third week on the value sank to 45 per cent making blood transfusion of 200 c.c. necessary After a few days the hemoglobin rose to 75 per cent but receded again to 50 per cent within 14 days, requiring another transfusion. Such transfusions were performed altogether five times whenever the value fell to about 50 per cent. The total volume of blood transfused was 1250 c c After the removal of the nail the hemoglobin values did not decline and remained normal

Krenslehner reports briefly about a case who developed marked pallor after medullary nailing it disappeared after removal of the nail A blood picture was not obtained

Slany made continuous blood picture studies in 15 patients with medullary nailing and found striking changes in the reticulocyte counts He informed me of his results before he published them in the Arch f orth & Unfallschirurgie Vol 43 1944 About 3–5 reticulocytes per 1000 red blood cells in the blood stream are considered normal values In blood dyscrasias they may rise to 500 After fractures the reticulocyte count is usually increased to 12–20 after medullary nailing to 24–48, returning to normal a few days after removal of the nail.

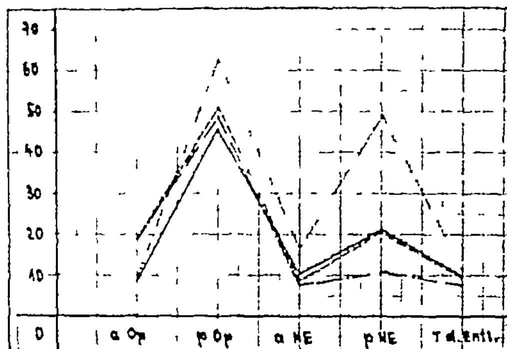


Fig 179

a Op = before medullary nailing p Op = after medullary nailing a NE = before extraction of the nail p NE = after extraction of the nail T d Entl = day of discharge

Average blood sedimentation rate curves as obtained by Dr Emilie Mayer in 53 cases of medullary nailing (10 of the femur 24 of the tibia 7 of the *humerus and 12 of the forearm*) *The highest peak* after nailing and after extraction of the nail is seen in fractures of the femur the lowest peak after removal of the nail is found in forearm fractures Tibia and humerus show about equal values *On the average* the sedimentation rate is increased 5 times after nailing and 2 times after extraction

Slany also found a rather considerable decrease in the red blood cells and the hemoglobin *content* These changes improved even before the removal of the nail although in contrast to Raisch he used no blood transfusions

Slany summarizes his results as follows

"1 The hematopoetic system reacts to medullary nailing with a marked increase of reticulocytes which persists as long as the nail remains in situ

2 After removal of the nail the reticulocyte values return to normal in a very short time

3 The larger the bone and the younger the individual, the *more immature white blood cell* (myelocytes and young forms) appear in the blood following medullary nailing in young patients this may occur repeatedly even after the first few days

4 Any fracture leads to a temporary increase of young or immature white blood cells and to an increase in reticulocytes

5 An increase in eosinophiles as reported by others in children occurs almost regularly to a varying degree in adults as well and disappears as *in children after removal* of the nail.

6 A considerable number of individuals react to medullary nailing with a more or less marked reduction in the number of red blood corpuscles and of the hemoglobin, which may at times assume a dangerous degree This anemia recedes spontaneously to a considerable degree even if the nail remains in situ

7 After removal of the nail an increase in red blood cells and of the hemoglobin is almost always the rule

In *lower leg fractures* the toes must be exercised actively throughout the full range of motion from the first day on, the ankle joint, knee and hip should not be actively exercised before one week has elapsed

In *humerus fractures* the wrist and forearm must be exercised actively through the full range from the first day on, the elbow joint and shoulder after one week.

In *forearm fractures* the fingers and the shoulder must be actively exercised from the first day on, the wrist and elbow joint after one week

General Symptoms following Medullary Nailing

Fever During the first week after nailing a slight rise of temperature to 37 5–38°C is common Such temperature elevations are however, frequently found in the wake of fractures without medullary nailing

Sedimentation rate of the red blood cells Dr Emilie Mayer at the suggestion of Dr Güttner examined the sedimentation rate in 53 cases before operation, after operation, and during the entire healing period until the removal of the nail The rate always increased after nailing but not more than with other treatment methods and usually returned to normal values within one week After removal of the nail a marked increase in the sedimentation rate follows in femur fractures, a lesser increase in other fractures (Fig 179)

Eosinophilia and reduction of hemoglobin content following medullary nailing Raisch reports the case of a 22 year-old female who developed an eosinophilia of 9 per cent following medullary nailing of a pseudarthrosis of the femur this disappeared gradually but not until after the removal of the nail six months later Otherwise the differential blood count showed no pathologic values in particular no shift to the left. Such changes have so far been observed only in children, not in adults.

In the case of Raisch, the hemoglobin before operation was 85 per cent, from the third week on the value sank to 45 per cent, making blood transfusion of 200 c c. necessary After a few days the hemoglobin rose to 75 per cent but receded again to 50 per cent within 14 days, requiring another transfusion Such transfusions were performed altogether five times whenever the value fell to about 50 per cent. The total volume of blood transfused was 1250 c.c After the removal of the nail the hemoglobin values did not decline and remained normal

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broken nails and corrosion damage will be discovered immediately and remedial measures can be instituted in time This prevents the patients from getting into the hands of others who may treat them for pains which may develop with various irradiations and injections as has been done in cases of aseptic necrosis of the femoral head and in cases in which the hip nail penetrated into the acetabulum

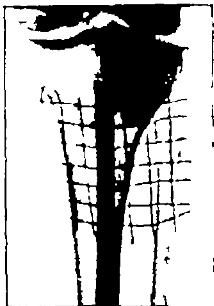


Fig 180 If the nail cannot be palpated through the skin before removal the wire net of Jeschke is used to localize it for the operation

Removal of the Medullary Nail

The medullary nail must remain in situ until the fracture has consolidated by bony union This can only be determined by X ray pictures in two planes These must be studied carefully because the presence of the nail obscures the picture to a certain extent so that a persistent non union of a part of the fracture line as frequently seen in the tibia (Figs 450, 451) may be overlooked Since the callus formation is neither hastened nor enhanced by the medullary nail, but rather, frequently delayed and stunted as compared with other methods one must be on guard against premature removal of the nail otherwise late angulation or pseudarthrosis (Figs 442–467) may develop It is best to wait 6–7 months. If the nail is removed as early as 8–10 weeks after insertion, as was frequently recommended before, great difficulties are met because it still sits very tightly

After 6 months the nail is somewhat looser and can then easily be extracted In most cases we perform this under local anesthesia We usually hospitalize the patient for a few days because occasionally we have noticed the development of hematoma and inflammation if the removal was done on an ambulant patient

If the nail cannot be palpated under the skin because it was inserted too deeply an X ray picture is taken, utilizing the wire net of Jeschke (Fig 180) for localizing the nail thus avoiding a large exploratory incision

Instruments for the removal of the medullary nail Since it is at times very difficult to remove a nail the tools for the removal must be strong The apparatus of Küntscher (Fig 71) Stör (Fig 83) and Pohl are adequate The hook which is

Medullary Nailing and Tuberculosis

I had occasion to observe two cases of compound fractures of the leg in whom immediate medullary nailing was followed by a not too severe infection of the fracture In one case two additional operative procedures were necessary, in the other the symptoms subsided without further interference They were bedfast for several months After one to one and a half years, both developed open pulmonary tuberculosis Probably this was a mere coincidence I mention it, however, because I have seen more than one thousand gunshot fractures of the leg, with incomparably more severe infections and much longer bed rest, in none of whom as far as I remember tuberculosis developed during the treatment This complication therefore, is extremely rare with other methods of treatment

In a 42 year-old rather weak man a malunited fracture was treated by open nailing Infection developed and after three months there was still thin seropurulent drainage from the nailing site A cold abscess developed over the sternum but the drainage from the nailing site was bacteriologically negative for tuberculosis

This case should not have been treated with medullary nailing because he was in poor general condition and over 40 years old

Post operative Observation and Nail Protocol

After operation many unforeseen incidents may occur such as angulation or shortening (Figs 161–178, 202–212) rotation (Figs. 222–231), migration of the nail (Figs 234–251 and 1130), fracture of the nail (Figs 252–263, 430–441, 468–478 and 1176 1194, 1216), damage from corrosion (Figs 198, 199 and 273–276), excessive callus formation (Figs. 390–423) and delayed callus formation (Figs 430–459), sequestrum formation in infections (Figs. 490–526) and other complications. For these reasons the patient must be under continuous post-operative observation until the *fracture has healed and the nail has been removed It would be wonderful if after* nailing and closing of the skin, we could dismiss the patient from our mind until he presents himself on some occasion, for the removal of the nail

For a reliable and accurate follow up of the patient even after discharge we keep special records for all fractures Also for those fractures treated with the medullary nail we keep a special file arranged by the various bones and containing all important data Name, age occupation mechanism of injury concomitant injuries and diseases date of injury date of nailing sketch of X ray pictures duration of hospitalization duration of ambulatory treatment and date of removal of the nail. Space is provided for notes about the final result at the conclusion of the treatment position of fragments condition of muscles and conditions of joints. Patients who are not under active treatment but still carry the nail must report once a month if complications may be expected, otherwise every two months, for accurate antero-posterior and lateral X ray control pictures the findings of which are entered in the records We use similar special records for vertebral fractures (see page I/238) In this way any developing complication such as angulation shortening rotation,

they must drive the nail home under all circumstances This is particularly true of open nailing if closed nailing has not been successful (see page 57) And yet there is nothing simpler than to interrupt the operation and insert a Steinmann pin or Kirschner wire for traction

In watching medullary nailings one sometimes gets the impression that a grim battle is in progress in which the opponent must under all circumstances be overcome or in which the broken bone must under all conditions be provided with a medullary nail I never noticed a similar attitude in other operations

OPERATIVE TREATMENT OF FRACTURES WITH THE MEDULLARY NAIL OF KÜNTSCHER THROUGH EXPOSURE OF THE FRACTURE FIELD

The outstanding advantage of the *closed medullary nailing* of Küntscher consists in the fact that the danger of infection which is the chief disadvantage of other operative procedures is reduced to a minimum because the medullary nail is introduced far from the fracture and without direct exposure of the fracture field In *open medullary nailing*, however, the fracture must be exposed widely and the danger of infection is therefore as great as with previous methods (see pages 82–85L) If infection does set in the consequences are sometimes worse because the entire medullary canal was opened and because an osteomyelitis may develop With the old methods only a localized osteitis was the rule Open nailing should therefore be undertaken only upon strictest indication and after careful consideration whether its advantages definitely outweigh its dangers

Theoretically, open medullary nailing comes into consideration under the following circumstances

1 In fresh closed fractures in which apposition of the fragments cannot be obtained in any other way
2 In fresh compound fractures
3 In fresh gunshot fractures
4 In infected and draining fractures
5 In old fractures
6 In mal united fractures
7 In pseudarthrosis
8 For shortening of the well femur
9 For bone shortening in nerve defects
10 For bone shortening in blood vessel defects

Open Medullary Nailing of Fresh Closed Fractures

Some surgeons suggest exposure of the fracture in fresh closed fractures if all efforts at closed reduction of the fragments are unsuccessful e g because of interposition of muscles (A W Fischer) or if difficulties arise during the driving of the nail (Hart and others) Severe infections have frequently followed this procedure

placed into the eye of the nail, has an annoying tendency to slip out during the hammering the clamp devised by Jörg Böhler (Fig 84) has proven very effective

How to Proceed if a Nail Can Neither Be Driven in Further nor Removed

If too thick a medullary nail has been used, especially on the femur, it may become stuck and extremely difficult to remove requiring hours of effort and great force Since I have heard of many fatalities following such an incident I recommend that the pulse and blood pressure be carefully checked when this happens. If the procedure is prolonged and hammer blows upon the bone are repeated frequently either when driving the nail or when removing it one will find as a rule that the pulse rate increases up to 160 or higher and the blood pressure falls **Whenever the pulse does not return to at least 120 beats per minute, the operation must immediately be interrupted,** otherwise the patient may fail to respond to all cardiac and vascular medication and even blood transfusion One must never forget that he is not working on a dead piece of material, but on a living human being Sometimes one gets the impression that all participants are completely unaware of this fact Not only is the surgeon under extreme tension, but the anesthetist is apt to watch the operation rather than the pulse and respiration In addition the onlookers offer advice and new instruments If no hack saw (Fig 70) is available, the protruding part of the medullary nail is wrapped in a sterile towel continuous traction with a Steinmann pin or a Kirschner wire is applied, the patient is quickly put to bed and heat applied because usually he is quite cool from excessive perspiration especially if he had not been dressed warmly as described on page 169 In the meantime a suitable saw or effective extractor can be secured. One must wait, however, until the patient has completely recovered and the pulse again becomes full and slow If this does not occur during the first 24 hours one may wait until the next day, when either a shortening or the removal of the nail will not endanger the patient. If a nail is sawed off, that part of it which remains in the bone can easily be removed without danger after a few months because it usually loosens spontaneously during this period

If while removing or driving a medullary nail the patient s general condition begins to fail *the operation must be interrupted at once* Cases have been reported in which fruitless efforts at reduction consumed 2–3 hours or more and were followed by the death of the patient Such occurrences are frequently heard of but rarely reported in the literature In the case histories which were available to me, death was listed in most cases as being due to *fat embolism* The prolonged anesthesia, the cooling of the patient and the vigorous procedure may alone cause the fatal outcome. Sometimes patients were operated upon who were in poor general condition In one case for instance endocarditis was found at autopsy One must not overlook the fact that medullary nailing is no emergency procedure and that it may, in contrast to many other operations be interrupted at any time without damage to the patient whereas its continuation may endanger life

It is strange that some surgeons believe that once they have started the operation

they must drive the nail home under all circumstances This is particularly true of open nailing if closed nailing has not been successful (see page 57) And yet there is nothing simpler than to interrupt the operation and insert a Steinmann pin or Kirschner wire for traction

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This is understandable if one considers the difficulties which sometimes arise from attempts at obtaining a perfect reduction They have been pictured to me drastically by various people If after hours of effort (A W Fischer writes of hour long "wrestling matches") it has not been possible to obtain good reduction, usually due to lack of adequate reducing apparatus, the skin and other tissues are severely damaged and therefore must not be exposed. It is then necessary to apply pin or wire traction, until the patient and the tissues at the fracture site have completely recovered from the accident as well as from the reduction maneuvers. Enthusiasm for medullary nailing must not lead one to insist upon it, and one must never forget that the old methods of treatment, properly used, can accomplish much good, and under such circumstances serve the purpose even better If satisfactory position cannot be obtained under continuous traction, which will be the exception, one may (after complete subsidence of the swelling and of the other symptoms, i e , after about 2 weeks or better, even later) perform an open nailing if another attempt at closed nailing with the help of satisfactory reduction apparatus should be unsuccessful Interposition of muscle tissue is in my experience, (see page 96) no cause for operative treatment with consequent exposure of the fracture because in spite of this interposition, callus formation will be satisfactory, provided the fragments are not distracted excessively This is proven by Figs. 307–316 from which it is also evident that even marked lateral displacement does not prevent callus formation if no distraction of the fragments exists (see page 107) If, however, a lengthening is produced as shown in Figs. 305, 306 it is not the interposed muscles which cause non union but the separation of the fragments in the longitudinal axis

In fresh closed fractures open medullary nailing should not be performed because the risk of infection is very great Open nailing is no emergency procedure Therefore the operative exposure of the fragments should under all circumstances be delayed until the swelling has subsided and the skin returned to normal showing no remnants of tension blisters or abrasions Furthermore all the contra indications enumerated on pages 8–10 for closed nailing hold equally for open nailing

Open Medullary Nailing of Fresh Compound Fractures

With every compound fracture the danger of infection is great because the fracture field is exposed by the accident itself Infection can in many cases be prevented by (1) a thorough excision of the wounds within the first 6–8 hours (2) insertion of a drain after closing the wound without tension as discussed in detail on pages I 106–130 and (3) uninterrupted immobilization. The question now is to determine whether medullary nailing increases the danger of infection or diminishes it I was formerly opposed to the usual methods of internal fixation in compound fractures because they require broad exposure of the fragments in addition, they were usually inadequate and therefore did not fulfill the requirement of complete uninterrupted immobilization as shown in Figs. 136 E I/195 420 421 E

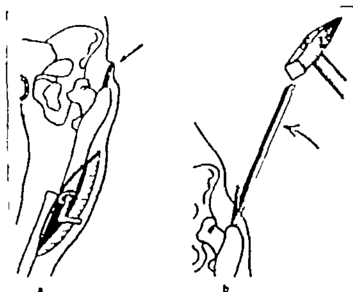


Fig 181 Fig 182

Fig 181 Introduction of the guide pin through the distal end of the proximal fragment in compound fractures and in osteotomy It is pushed through the greater trochanter until it bulges the skin which is then incised over it in a 3 cm long transverse incision The pin is then pushed out further

Fig. 182. The medullary nail is placed over the guide pin and driven in (from the original drawing of Küntscher)

I/1037–1042 and II 2094–2105 and II 2138 These two disadvantages do not prevail in medullary nailing The nail can be introduced without further exposure of the fragments and in properly selected cases provides a firm permanent fixation as proven by Figs 608–617, 618–638, 641–648 and 657–670 In the comminuted fracture of the femur shown in Figs 618–638, the medullary nail offered particular advantages. Without its use it probably would not have been possible to obtain nearly as satisfactory a result

Even with early, thorough debridement compound fractures of the lower leg and of the forearm are subject to infection because those bones are located closely under the skin which is frequently severely damaged by the trauma. If a slightly displaced fragment presses against such skin, it may become necrotic, the bone becomes exposed and infection may set in. We were hoping that this danger could be reduced with the medullary nail Unfortunately, however this has not been the case for the most common type of compound fractures namely those of the lower leg

An accurate opinion about the value of any treatment method can only be formed by comparing a *consecutive series* of cases which have been under observation for at least 1–3 years with another comparable series

From the middle of 1941 to the middle of 1944 we treated 18 compound fractures of the femur, 47 compound fractures of the lower leg, 6 compound fractures of the humerus and 6 compound fractures of the forearm with medullary nailing at our Accident Hospital in Vienna. For comparison we used our 306 compound fractures of the long bones of the years 1926–1934 which Chalt had analyzed most meticulously in every respect and from which the duration of consolidation, the duration of

treatment, the anatomical and functional end results and all possible incidents are evident

Of the 18 *compound fractures of the femur*, 17 healed without wound complication In one case a localized infection developed after 6 days and later a small sequestrum separated This was probably caused by the fact that contrary to our standing orders the muscles were pulled together with several catgut sutures Healing occurred with no shortening and full function Since infection occurred in 1 out of 18 cases, the result in this respect is not as good as in our previous series of 23 compound fractures of the femur which all healed without wound complications, as reported by Ehalt in his book Nevertheless we will continue to treat compound fractures of the femur in the future with the medullary nail because this constitutes a great simplification of the care and because no additional continuous traction or plaster cast is needed except in comminuted fractures (Figs 618 638) Even in long spiral fractures with a long third spiral fragment (Figs 570-573) no additional plaster cast or continuous traction is required if the fragments are wired together with 2 or 3 loops of wire Callus formation is delayed, but this is insignificant because the nail provides such a firm support that the patients can work even before the bone has consolidated firmly (Figs 618-638)

The indications and contra indications for open nailing of fresh compound fractures of the femur are enumerated on pages 164-166 If acute infection should set in the wound and the nailing site must immediately be exposed widely The final result may be entirely satisfactory nevertheless, as shown in Figs 490-503

With the use of *penicillin* the results might possibly be improved further

Of 6 *compound fractures of the humerus*, all healed without wound complications The results are in this respect equally as good as those obtained in our 24 cases reported by Ehalt Because of the danger of osteomyelitis I will, however, in the future, not use open medullary nailing except occasionally

Of our 46 *compound fractures of both leg bones* only 36 healed without serious wound complications in 10 (21 7%) severe infection developed Ehalt[1] reported in his book that in 7 (6.2%) of our 117 compound leg fractures serious infection developed and in 2 (6 7%) of 29 isolated fractures of the tibia. It is evident, therefore, that infections are three times as frequent following the use of the medullary nail Besides this any infection in nailed cases is much more serious than in others because the inflammation involves not only the soft tissues and the fracture ends, but may involve the entire medullary canal.

Osteomyelitis never developed in the previous series, but only a local osteitis, limited to the fracture site Now we found sequestra not only at the fracture ends but also in the medullary cavity as shown in the cases of Figs. 219 and 864-873 Of the other cases we do not know whether they developed such sequestra later

Suppurative arthritis in knee and ankle joint never occurred before if the joint itself was not involved primarily Of the 46 nailed cases, two developed purulent

[1] Ehalt Die offenen Brüche der langen Rohrenknochen. Vienna Maudrich, 1938.

arthritis of the ankle joint (Figs 213-221 and 894-901) and one a seropurulent inflammation of the knee joint (Figs 864 873)

Permanent sinuses never resulted before In some of the nailed cases they persisted for 2-3 years and we do not know whether they will close or when

Pseudarthroses were previously never observed in aseptic cases whereas they occur not infrequently now, as shown in Figs 430-441, 442-459

The *duration of treatment* is now much longer than before the use of the medullary nail even in aseptic cases (Figs 442-459)

Because of the frequent occurrence of severe infections I have greatly restricted the use of the medullary nail in compound leg fractures since the end of 1941 (see page 277) Thereupon the results were better in 1942, only to became worse again in 1943 when the indication was relaxed The younger physicians accepted the occasional complications without misgivings because they were not acquainted from their own experience with the results of previous methods and because the desire to perform as many nailings as possible was very pronounced Spectacular results were frequently ascribed merely to the new method e g Figs 856-863 and 874-883 Yet the good results in case 856-863 must be ascribed to unusually fortunate circumstances because such ring shaped fragments are usually completely sequestrated by medullary nailing That formerly without medullary nailing we obtained full restoration much more quickly is shown in Figs I/160-169 and II/2512-2541 and the numerous illustrations in Ehalt's book

In 1943 an osteomyelitis developed suddenly in one case 6 months after aseptic healing (Figs 884-893) and in another 10 weeks later (Figs. 910-915) When a compilation of all cases revealed that the duration of treatment was longer than before, even in cases which healed aseptically, I prohibited open medullary nailing of fresh fractures of the leg bones in my jurisdiction because in my experience it only shows disadvantages and no advantages

In order to check whether my directives which the younger physicians were unwilling to understand were justified I had the results compiled from five other hospitals covering a total of 56 fresh compound fractures of both leg bones treated with the medullary nail Their results were even worse than ours An additional complication was that in cases in which amputation became necessary it was frequently very difficult to remove the nail It was interesting however that most surgeons were quite satisfied with their results, before this study was made they were lacking in overall insight into this matter

In our 117 compound leg fractures Ehalt found serious wound complications in 6 2% in addition to 8 7% infections which required no incisions, further dry necrosis of the skin in 15 8% which separated without elevation of temperature and which did not materially delay the healing time If in these cases with skin lesions and low grade inflammations a nail had been present in the underlying medullary cavity, the inflammation would have spread into the medullary canal and possibly to the posterior aspect of the bone where a progressive abscess may form. This explains why serious infections are much more common in nailed cases than in others

Of the *6 compound forearm fractures*, one case had to be amputated on the next day because both arteries had been severed, 4 cases healed without wound complications (Figs 1117–1126 and 1127–1134) In the case of Figs. 1117–1126 a pseudarthrosis developed later In one case (Figs 1136–1145) a creeping infection caused the formation of such large massive sequestra as I have never seen without nailing The case of Figs. I/149–159 had a similar injury His result was very good without using the nail. I therefore no longer permit the use of the medullary nail in fresh compound fractures of the forearm

Open Medullary Nailing of Fresh Gunshot Fractures

In 1943 (Der Chirurg, No 1, 1943) I suggested the nailing of fresh *gunshot fractures of the femur* This I performed twice at the battle front (Figs 657–670 and 671–683) and once at home in a man with a fracture similar to Figs. 618, 619 The latter healed without wound complications.

Open nailing of fresh gunshot fractures of the femur may be performed at the front only if the requirements given on page 209 are fulfilled This is probably not often the case

In my three cases the wounds were closed with sutures after insertion of drains. The nail insertion was left open *As a rule the wound should be left wide open* The case described on page 201 shows that the nail may heal in without sinus formation. The pictures shown in Figs. 490–503 prove that in spite of marked local infection, the adjoining medullary canal may not be involved in the inflammatory process. Whether the method is suitable for extensive use at the front must be decided after further observations Under the protection of penicillin the indication for this operative procedure can probably be broadened

Considering the unfavorable average results which I have observed from medullary nailing of fresh *compound fractures of the lower leg and forearm*, I do not consider this method advisable in gunshot fractures I saw several gunshot fractures of the lower leg which had been so treated by other surgeons The results were not good

The same applies to *gunshot fractures of the humerus*, since immobilization of these fractures with splints and plaster casts is much simpler and less dangerous.

Open Medullary Nailing of Infected and Draining Fractures

I have never been able to decide in favor of nailing infected or draining fractures although Ehrlich, Häbler and Küntscher reported individual successful cases Nailing is tempting in infected fractures with marked lateral displacement and in draining pseudarthroses which are likely to take months or years for healing

Femur fractures Open medullary nailing of infected fractures of the femur seems permissible The gunshot fracture described on page 205 illustrates that it may be done without causing appreciable harm I received however, many reports of fatalities following open nailing of infected fractures such as one concerning a man who had a small sinus on the outer side of the femur without temperature rise

for several weeks After the operation an extensive phlegmonous infection set in with purulent arthritis of the hip to which the man succumbed Such cases are rarely published, hence only favorable results are found in the literature

From my experiences with open nailing of fresh *compound fractures of the leg bones* I do not believe that it can be recommended for infected fractures

I had an opportunity to see a number of humerus and forearm fractures which were nailed by others in a stage of suppuration and drainage, some in connection with removal of sequestra The results were unfavorable in most cases

If infected and draining fractures are nailed it is essential to leave the wounds over the fracture wide open and that the wound through which the nail is inserted not be closed with sutures, otherwise abscesses and progressive cellulitis may develop, especially in the gluteal region

Success in individual cases or in a small series of cases cannot form the basis for recommending generally a procedure which in itself is dangerous A decision as to the advisability of this procedure will be possible only after a careful study of a *continuous* series of at least 50–100 cases will have been made, covering a period of at least 1–2 years, accompanied by X ray pictures, tabulations and case histories similar to the books of Ehalt,[3] Krömer,[4] and Böhler Jeschke[5] or the publications of Blechschmied[6] and Böhler[7,8]

Open Medullary Nailing of Old Fractures

Old fractures in which the callus formation has been delayed by excessive traction and in which considerable angulation and shortening are present are particularly suited for open medullary nailing The shortening must be eliminated before operation by continuous traction on the femur if the shortening is more than 4 cm, on the lower leg if it is more than 2 cm and on the humerus if it is more than 3 cm, or, the bone must be shortened during the operation since otherwise serious complications may result (see page 239 and Figs 767–770)

Femur fractures, especially those of the middle and proximal third are suited for open medullary nailing If angulation with good callus formation and without shortening is present in the distal third as in Figs 693, 694, it is much simpler and less dangerous to straighten the bone by means of the osteoclast of Phelps Gocht (Figs. 934 E, II/2746) or of Schultze (Figs II/2129, 2130) and to apply a plaster cast This case would probably have shown firm union in 5–6 weeks

[3] Ehalt Die offenen Brüche der langen Röhrenknochen und ihre Behandlung. Vienna, Maudrich, 1938.

[4] Kromer Die verletzte Hand. Vienna, Maudrich 1938 and 1945

[5] Böhler Jeschke Die operative Behandlung der Schenkelhalsbrüche und Schenkelhalspseudarthrosen. Vienna, Maudrich, 1938

[6] Blechschmied Behandlungsergebnisse der Olecranonbrüche. Arch. klin. Chir., 187 No. 1 1936.

[7] Böhler Behandlungsergebnisse der Oberschenkelbrüche Arch. f orth. u. Unfall-Chir., 35 No. 4 1935

[8] Böhler Die Ursache der Myositis ossificans nach Ellbogenverrenkungen. Fortschritte der Röntgenstrahlen, 53 No. 6 1936

On the *lower leg* and *humerus*, only fractures in the middle third are suitable The indication for operation must be considered very carefully, especially on the lower leg If, for instance, in the case pictured in Figs 515–526 with delayed callus formation merely an osteotomy of the fibula had been done and the angulation eliminated by manipulation it probably would have shown firm union within 8–10 weeks whereas, after medullary nailing large medullary sequestra formed and the fracture has not yet healed firmly

On the *forearm* such operations should never be performed The bones, after having been straightened, can be retained in a plaster cast without danger of in fection.

Since the operation is never urgent it should only be performed when the general condition is good and if all basic requirements listed on pages 6–10 for closed medullary nailing are fulfilled

Open Medullary Nailing of Mal united Fractures

If in femur or lower leg fractures a shortening of more than 3 cm and angulations or torsions of more than 15° remain, the patient usually limps, and later as a rule, sometimes even after 10–20 years disturbances in the knee joint and occasionally in the hip and ankle joint develop For these reasons the displacements should be eliminated if the general and local conditions permit. Since the operation is never urgent, all contra indications enumerated on pages 8–11 should be taken into con sideration Before the operation an exact blood picture should be obtained Patients in whom the red cell count or the hemoglobin content is reduced from previous loss of blood or through a long convalescence must be excluded from the operation Especially operation on the femur must be taken very seriously As a rule only patients under 40 years should be operated upon. A blood donor should be in readiness

Shortening of more than 4 cm on the femur or more than 2 cm on the lower leg and more than 3 cm on the humerus must either be corrected by continuous traction or by bone shortening before one proceeds with medullary nailing In the literature and in re-examinations one repeatedly meets cases in which the neglect of these rules has led to wound infection, since the forcible attempts to eliminate the shortening during the operation cause a tearing of the soft tissues and since the operation is protracted by the difficulties met in trying to overcome the obstacles.

I have been advised of a comparatively great number of cases in which such operations were followed by death either on the operating table or after a few hours, due to circulatory failure or later from infection. If the outcome is not as unfavor able, the forceful tearing of muscles leads to marked restriction of motion later

In mal united fractures such unfortunate results can be avoided by severing the bones in the open wound and by lengthening through gentle skeletal traction further by nailing but not until the shortening has been corrected and the wound has healed, or by shortening the bone as shown in Figs 754–760 In pseudarthrosis and fractures not yet consolidated it is sufficient to break up under short anaes-

thesia the fibrous union over a wedge or with the Phelps-Gocht osteoclast and to apply skeletal traction as shown in Figs 771–779 and 922-931 In fractures which had been infected, this simple maneuver will reveal whether a tendency to a flare up of the infection exists if none occurs at this time, probably none will follow medullary nailing if performed one week later If these rules are not followed, the most serious consequences may occur as in Figs 767–770 When after a few days the shortening is eliminated the apposition of the fragments and the insertion of the medullary nail will offer no particular difficulties

Following *infected fractures* nailing must not be performed within 6 months in cases of light infection, and in cases of severe infection not earlier than 1 year after closure of all sinuses With the use of *penicillin* these waiting periods can in all probability be reduced considerably If large scars attached to the bone and extensive muscle destruction exist and if the knee joint will probably not become mobilized such major operations should not be performed

In summarizing one must state again that medullary nailing in fresh closed fractures and in old fractures as well as in pseudarthrosis is no urgent measure and should therefore not be performed just out of enthusiasm for the new method without due regard for the local and general condition of the patient

Open medullary nailing has the great advantage that in properly selected cases of femoral fractures in the middle and proximal third, no additional plaster cast is needed whereas this is essential if only wire, plates and screws or bone grafts are used In the case pictured in Figs 705, 706 simple osteotomy followed by plaster cast or continuous traction would have been simpler

Before nailing, the fragments must be put in exact apposition If angulations are present, wedges must be removed for their correction It is not sufficient to cut the bone transversely because a gap will then develop on one side when the bone is straightened a gap which cannot be bridged by the callus This may lead to a fracture of the medullary nail (Figs 252–263) These accidents happen only because of the erroneous belief that the medullary nail has a callus-stimulating effect Fractures of the tibia the humerus and forearm should be severed obliquely and the proper wedges removed similar to Figs II/2570–2575 If an oblique osteotomy is performed in these cases, a wire suture is usually sufficient and medullary nailing need only occasionally be considered If a bone is cut transversely in the middle of the shaft the callus formation is always extraordinarily slow For fractures near the joints transverse osteotomy without medullary nailing is very suitable (Figs II/2576–2581)

Open Medullary Nailing of Pseudarthroses

In pseudarthrosis of the femoral neck no matter what the age of the fracture or of the patient bony union can be obtained if the fragments are reduced without exposure and freshening of the fracture surfaces and firmly united with a three-flanged nail and proper weight-bearing instituted (Figs 644a and 654b E II/1818–1870)

On the *lower leg* and *humerus*, only fractures in the middle third are suitable The indication for operation must be considered very carefully, especially on the lower leg If, for instance, in the case pictured in Figs. 515–526 with delayed callus formation, merely an osteotomy of the fibula had been done and the angulation eliminated by manipulation, it probably would have shown firm union within 8–10 weeks, whereas after medullary nailing large medullary sequestra formed and the fracture has not yet healed firmly

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Fig 186 Fig 187 Fig 188 Fig 189

September 9 1941 October 17 1942

Figs. 186, 187 In the antero-posterior view the guide pin and medullary nail are apparently in correct position. The lateral view shows that the guide wire and medullary nail have left the greater trochanter because they were inserted without previous reduction and without lateral fluoroscopy

Figs 188, 189 After open osteotomy a nail was driven in without coapting the fragments and holding them firmly with a Lambotte clamp and without inserting the guide pin first. Therefore, the nail came to lie superficially in the anterior portions of the bone and a valgus position and recurvation developed. The nail was also too short Treated elsewhere

but on the contrary certain disadvantages The cases of Figs 940–943 and 944–951, would have healed just as quickly with a mere circumferential wire suture without the nail The fracture of Figs 952–959 would have united much sooner with bone-grafts and Figs 960–971 give the impression that the medullary nail delayed callus formation The use of the medullary nail in defect pseudarthrosis (Figs 972–975) is completely erroneous Even if the medullary nail would stimulate callus formation, it could hardly be assumed that it would bridge such gaps Medullary nailing should be used very cautiously in pseudarthrosis of the *tibia* because if infection sets in large medullary sequestra will separate (Figs 511–526) Figures 860–867 E, II/2582–2609 show that with the old methods we obtained better results in a shorter time and with less risk For this reason I have discontinued the use of the medullary nail for the treatment of pseudarthrosis of the tibia.

For pseudarthrosis of the *humerus* medullary nailing offers no particular advantages. The case of Figs 468–479 would have healed just as quickly using oblique or Z-shaped freshening of the fractures and two transverse wire sutures as it did following the last operation employing a long and thick medullary nail and two longitudinal wire sutures The case of Figs 1064–1073 would probably have healed



Fig 183



Fig 184



Fig. 185

Fig 183 The guide pin deviates medially

Fig. 184. The guide pin in the right location.

Fig 185 The guide pin was introduced without previous reduction. Treated *elsewhere*.

as I have proven long ago (Böhler, W Kl W No 44 and 49, 1934, No 1 and 7, 1935 Zbl. f Chir No 3 and 30, 1936, und Böhler Jeschke "Operative Behandlung der Schenkelhalsbrüche und Schenkelhalspseudarthrosen", Maudrich, Vienna, 1938) Among the reported cases was a pseudarthrosis of 22 years standing (Figs. II/1866–1869) This surprising result is only possible because we are dealing with cancellous bone

In pseudarthrosis of the *scaphoid of the wrist* treated with a wire I have frequently seen failure (Figs. 491 E I/1228) due to lack of post-operative functional strain upon the fracture

In pseudarthrosis of a *shaft* bony union will only occur if the sclerosed fracture ends are exposed and thoroughly freshened Furthermore the freshening on the tibia, humerus and forearm should be done obliquely or Z-shaped, because in transverse freshening callus formation is extremely slow or may never occur

For pseudarthrosis of the *femur* medullary nailing represents a great simplification because the operation is finished after freshening the fragments and after the insertion of the nail whereas formerly a bone graft had to be transplanted to prevent shortening a procedure which was time-consuming and technically not simple A graft never provided nearly so much stability as the medullary nail furnishes (Figs 735–747) For a pseudarthrosis of the *proximal and middle third* (Figs. 748–753, 754–760) the medullary nail provides sufficient stability for those distal to the middle portion (Figs. 771–779) a supplementary wire suture or plaster cast must be used.

In pseudarthrosis of the *lower leg* I have seen no definite advantages from nailing



Fig. 190
August 21 1941



Fig 191
January 25 1943

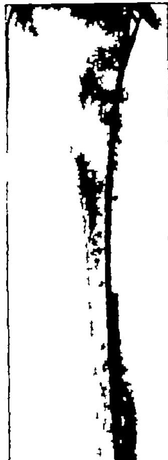


Fig. 192
December 1 1941

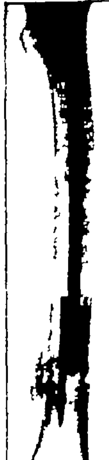


Fig 193
January 12 1942

Fig. 190 The nail was inserted distal from the greater trochanter and split the bone (Observation of Sprengell, Zbl f Chir No 7 1942)

Fig. 191 The nail has been inserted through the lateral part of the greater trochanter splitting off a sliver of bone. Below it is the original spiral fracture.

Fig 192. Break of the guide pin. The point has not yet reached the fracture Another thinner guide pin has been introduced over it.

Fig. 193 Same as Fig 192 after 5 weeks. The nail was inserted over the thin guide pin It did not reach the fracture. The fragment from the broken guide pin was driven past the fracture and prevents lateral displacement. Corrosion effect at the broken surface of the guide pin Good callus formation on the inner side of the fracture (Observation of Sprengell, Zbl f Chir No 22 1942)

This type of bone shortening may as a rule be performed only in young people up to the age of 25 or at the most 30 years who are otherwise in good general health. I have not seen any wound disturbances in such cases to date Lately, however I received the case history of a 20-year-old female patient in good general health who suffered from a 6 cm congenital shortening of the left femur The right leg was shortened by 6 cm. High temperature developed on the same day After removal of the suture a hematoma was evacuated and the temperature fell. Fourteen days later the temperature rose again and gradually assumed a septic curve The patient died after 3 months of septicemia, apparently arising from the bone marrow since no other abscesses were found

quickly following Z-shaped freshening with two transverse wire sutures In Figs 1082–1087, the two transverse wire sutures would have been sufficient and in Figs. 1074–1081 oblique freshening and wire suture would have been much simpler In Figs. 1088–1097 a large bone graft without medullary nailing as shown in Figs. 196–203 E, I/279–286 would probably have brought about union in a short time

In pseudarthrosis of the *forearm* the medullary nail may become dangerous as shown in Figs. 1166–1171, 1186–1197 and 1222–1227 With a step-shaped freshening (Figs 182–185 E 422–428 E I/265–268, I/1044–1050, I/1051–1058) or bone grafting (Figs 186–191 E, I/269–274, I/1059–1062, I/1228–1233 and I/1234–1241) much better results can be obtained with greater safety

Since it developed that the medullary nail has no callus-stimulating effect, it is of value only for pseudarthrosis of the femur

Open Medullary Nailing for Shortening of the Well Femur

If one leg is shorter as a result of a fracture or from some other cause the patient limps and in the course of years joint damages may develop on the well leg and on the spinal column With marked shortening which cannot be overcome by a lift on the shoes, the hip, knee, and ankle joint of the non injured leg may suffer The knee joint may become loose on the medial side valgus deformity and even a flail joint may develop causing such marked instability that walking becomes impossible without a brace The faulty weight-bearing causes the development of flat foot. Frequently arch supports have to be prescribed. The necessary tilting of the pelvis causes a scoliotic curvature of the spine with late arthrosis of the vertebral joints.

Differences in length between the two legs can be eliminated operatively either by lengthening the short leg or by shortening the longer leg Where shortening as well as angulation and rotation are found following a closed or non infected compound fracture of the femur osteotomy at the old fracture site will permit the correction of all deformities by continuous traction After this has been accomplished a medullary nail may occasionally be used. If severe infection has preceded and if the bone and the soft tissues are markedly changed, the injured leg may be straightened but as a rule it may not be lengthened since the lengthening may cause a flare up of the infection. For these cases the best and simplest method is to shorten the well leg After the bone has been shortened by the removal of a section of proper length from the narrowest part, the two fragments are united by a medullary nail (Figs. 705–722) and the patient can get up after 3 weeks without additional support. The muscles shorten to the right size in the course of a few months (Figs. 723–734) If the bone is cut transversely callus formation is very slow (Figs. 717–722) The use of the leg is not hindered because the medullary nail gives sufficient stability In order to hasten callus formation it is sometimes preferable to cut the femur obliquely which has the advantage that the fragments cannot rotate against each other



Fig. 190 August 21 1941 | Fig. 191 January 25 1943 | Fig. 192 December 1 1941 | Fig. 193 January 12, 1942

Fig. 190 The nail was inserted distal from the greater trochanter and split the bone (Observation of Sprengell, Zbl f Chir No 7 1942)

Fig. 191 The nail has been inserted through the lateral part of the greater trochanter splitting off a sliver of bone Below it is the original spiral fracture.

Fig. 192. Break of the guide pin. The point has not yet reached the fracture Another thinner guide pin has been introduced over it

Fig. 193 Same as Fig 192, after 5 weeks. The nail was inserted over the thin guide pin It did not reach the fracture The fragment from the broken guide pin was driven past the fracture and prevents lateral displacement Corrosion effect at the broken surface of the guide pin Good callus formation on the inner side of the fracture (Observation of Sprengell, Zbl. f Chir No 22, 1942)

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Fig 194 Fig 195 Fig 196 Fig 197
February 17 1941 April 3 1941

Figs. 194 195 The use of too thick a nail caused the distal fragment to be pushed away from the proximal fragment and a gap of 15 mm was produced. These X ray pictures were taken 4 weeks after fracture and nailing Beginning callus formation

Figs. 196 197 Same as Figs. 194 195 after another 6 weeks. In spite of the separation of the fragments, callus formed because the fragments were immobilized uninterruptedly by the nail and because they are well nourished by the surrounding muscle cuff

Open Medullary Nailing following Bone Shortening for Nerve Defects Due to Gunshot Wounds

Nerve suture is successful only if the healthy nerve endings can be approximated without tension after removal of all scar tissue If this is not possible by flexion of the joints, the bones may be adequately shortened and provided with a medullary nail.

Open Medullary Nailing following Bone Shortening for Vascular Defects Due to Gunshot Wounds

If after an operation for aneurysm a vascular defect is present, suture of the blood vessel is sometimes possible by adequate flexion of the joints Otherwise ligation or a grafting of a section of the saphenous vein must be performed Instead of this the bone may be shortened and provided with a medullary nail which is simpler and less dangerous than the transplantation of a piece of vein The operation probably should be considered only for involvement of the femur



Fig 198 Fig 199 Fig 200 Fig 201

July 1 1941 February 14 1943

Figs. 198, 199 Same as Figs 194 195 after 4½ months. The greater part of the gap is filled with callus. An area of bone absorption at the tip of the nail indicates corrosion. On the medial side of the tip of the nail, periosteal appositions have developed in response to irritation from the corrosive process.

Figs. 200 201 Same as Figs 194 195 after 2 years, and 1½ years after extraction of the nail. Bony consolidation Some thickening of the bone at the site of corrosion (Observation of Ehrlich, Zbl. f Chir No 30 1941)

Indications and Contra indications for Open Medullary Nailing

Küntscher (Zbl f Chir No 25 p 1139, 1941) considers surgical exposure of the fracture site the worst of all treatments. Open nailing however is possible only if the fracture is exposed Because this method, in contrast to closed medullary nailing, carries the risk of infection, and because the medullary nail unfortunately does not stimulate callus formation but occasionally even delays it the indication for this operation must be strictly limited If it were possible to increase the callus formation at will and thus speed the healing by using a certain metal for the nail, one could put up with occasional infection

If all indications and contra indications for closed medullary nailing (see pages 6–11) are taken into account open medullary nailing comes into consideration chiefly for fractures of the femur only exceptionally for other fractures

In the *femur* the medullary nail will give sufficient stability, without additional external support in suitably selected cases (for indications see page 164) Open medullary nailing is suited for fresh compound fractures, mal united fractures and



Fig. 202 Fig. 203 Fig. 204 Fig. 205 Fig. 206
November 23 1941 Nov 23 1941 December 20, 1941

Figs. 202 203 Compound leverage fracture of the right leg between middle and distal third in a 16-year-old office-girl who was knocked down by an automobile. The wound was excised and the skin closed after insertion of a drain

Fig 204 Same as Fig 203 To immobilize the fragments for medullary nailing, a wire was driven through the os calcis and a cast was applied to the leg in the screw traction apparatus, contrary to the usual practice and the nail was inserted The nail emerged in front of the distal fragment. The nail was then retracted and re-inserted without a plaster cast.

Figs. 205 206 Same as Figs 202 203 after 4 weeks. The nail is too short and too thin. Therefore a circular cast was applied to just above the ankle joint, but this cast is also too short. For immobilization of the fragments, a regular walking cast incorporating the ankle joint is required.

pseudarthrosis Furthermore it may be considered for bone shortening on the well leg for equalization and for bone-shortening on the injured leg for the repair of gun-shot defects of vessels and nerves In fresh gunshot fractures of the femur the indication for operation must be considered very carefully The results in infected and discharging fractures have not yet been determined

We formerly excluded fresh closed femoral fractures from medullary nailing, now we perform it occasionally under the protection of penicillin

On the *lower leg* fresh closed fractures should be excluded from medullary nailing because of the danger of infection. I have prohibited the use of this method in fresh compound fractures in my jurisdiction because I have seen such detrimental results (see page 277) In fresh gunshot fractures of the lower leg the results are not likely to be better Infected and discharging leg fractures should likewise be rejected In old leg fractures I have seen no advantage from medullary nailing Usually open or closed severance of the fibula produces quicker results and is less dangerous. Shortening of the well lower leg for equalizing with a shortened injured leg or shortening of the injured leg for gunshot defects of nerves and blood vessels will, for all practical purposes hardly ever have to be considered

On the lower leg open medullary nailing is indicated only in mal united fractures of the middle third (Figs. 932–939)



Fig 207 Fig 208 Fig 209 Fig 210 Fig 211 Fig 212

January 31 1942 March 11 1942 March 13 1942 Sept. 16 1942 March 17 1943

Fig. 207 Same as Fig 205 after 6 weeks. In spite of the medullary nail and the short cast a slight varus angulation of 5–6 developed

Fig. 208. Same as Fig 205 after another 6 weeks. The varus angulation now is 12–13° Increased loose irritation callus on the medial side Fracture line open throughout The nail migrated upwards by 1 cm.

Fig. 209 Same as Fig 208 after straightening the leg with a Phelps-Gocht osteoclast. Angulation corrected Fracture line gapes on the medial side. Walking cast for 6 weeks.

Fig 210 Same as Fig 209 after 6 months. The tibia is straight the greater part of the fracture line is still visible. Nevertheless, the nail was removed

Figs. 211 212. Same as Figs 202 203 16 months after injury 12 months after refracture, and 6 months after removal of the nail Bony consolidation A slight varus angulation and recurvation of 5–8° recurred because the nail was removed too soon This fracture should not have been nailed, because it was compound and because the distal fragment was too short.

On the *humerus* I have never seen an ill effect from open medullary nailing of fresh compound fractures. If inflammation sets in, however, the consequences are much less harmful when no medullary nail is used I saw no advantages from medullary nailing in pseudarthrosis of the humerus For fresh closed fractures open medullary nailing should be rejected because of the danger of infection

On the *forearm* open medullary nailing should not be used at any stage

Open nailing may occasionally be effective in *pseudarthrosis of the clavicle,* but not for fresh closed fractures of this bone

After a repeated careful study of my own cases as well as of published cases, and after comparison with other methods, I make the following statement

Open medullary nailing is suited only for fractures of the femur (fresh compound old fractures, mal united fractures and pseudarthrosis) Fresh closed fractures should be excluded

In all other fractures open medullary nailing entails on the average more disadvantages (danger of infection osteomyelitis delayed callus formation) than advantages and is therefore as a rule, not suited for these fractures



Fig. 213 Fig. 214 Fig. 215 Fig. 216

December 9 1941 December 9 1941

Figs. 213 214 Compound fracture of the left leg with marked displacement in a 47 year-old mason who was run over by an automobile. The proximal fragment protruded 8 cm. from the wound and was badly soiled with street dirt and hay Immediate wound excision medullary nailing and skin suture after insertion of 2 drains. Posterior plaster splint.

Figs. 215 216 The nail is too long Its tip protrudes into the joint.

COMPLICATIONS OF MEDULLARY NAILING

The number of untoward incidents, which may occur with medullary nailing, is unbelievably great and reports about new incidents are received continuously One must be familiar with them in order to be able to avoid them.

The worst complication is death It has followed medullary nailing with comparative frequency The causes were

1 Operating during shock (see contra indications on pages 8 and 56)

2 Use of too thick a nail. Because it was frequently impossible to drive such nails further in or to extract them the nail was hammered back and forth for an hour or more until shock was produced

3 Neglect to have a donor ready for blood transfusion in old femoral fractures or in pseudarthrosis.

4 Infection. This frequently followed inaccurate indication and preparation and defective technique

The vast majority of non fatal complications arose from neglect to measure accurately the width of the medullary canal and the length of the bone before operating Therefore nails which were either too thick or too thin, too long or too short, were used Other causes of complications are lack of the necessary instruments and apparatus, and inaccurate reduction before the introduction of the guide pin and the driving of the nail. In addition there are the disturbances due to defective material.



Fig 21 Fig 218 Fig 219 Fig 220 Fig 221

March 31 1942 June 23 1942 April 15 1944

Figs. 21 218 Same as Figs 213 216 after 4 months. Ten days after injury an infection developed which spread into the joint. The nail protrudes 14 mm. into the ankle joint.

Fig. 219 After removal of the nail Besides the central medullary sequestrum at the distal end of the proximal fragment, another central sequestrum can be seen 4 cm. above the fracture line

Figs 220 221 Same as Figs 213 214 after 22 months. Bony union with recurvation of 12 Bony ankylosis of the ankle joint. Walks with a cane. Compound fractures as close to the ankle joint as this must not be nailed.

Wrong Position of the Guide Pin and the Medullary Nail

The guide pin must be inserted into the femur through the posterior part of the ridge of the greater trochanter in the direction of the medullary canal If it is inserted at a different site or in a different direction, it will leave the bone (Figs. 183, 186, 187) In order to determine the exact position of the guide pin its position must be checked by fluoroscopy in two planes during its insertion If only antero-posterior fluoroscopy is used as in Fig 186, the guide pin may leave the bone as shown in Fig 187

In fractures distal to the middle angulations must be eliminated before the guide wire is inserted, otherwise the nail will permanently retain mal-position (Figs 185, 188 189 390–397, 767–770)

Wrong insertion of the guide wire can be prevented by continuous biplane fluoroscopy

Faulty insertion of the nail can be prevented by not inserting the guide wire until exact reduction of the fragments has been obtained

Splitting of the Bone by the Medullary Nail

This has been reported by Sprengell (Fig 190) It can only occur if the guide wire is inserted on the outside of the greater trochanter and if the nail is thus not driven into the medullary cavity from above but from the side We had a similar experience with our 49th case of femoral nailing (Fig 191)



Fig. 222 Fig 223 Fig 224 Fig 225
February 18 1942 February 18 1942

Figs. 222–225 Fracture of the left femur and lower leg, 4 months after injury and medullary nailing. Suffered by a 58-year-old bread-delivery man who was knocked down by a horse Both nails are too short and too thin. Therefore cloudy callus formed. Fracture line still open on both bones, because of defective immobilization Since the nail was too short and too thin the knee joint rotated outward between the fractures of the femur and the lower leg (see Fig. 227)

If the medullary nail is too thick, fine cracks will be produced in the bone, as Küntscher has already shown, but no actual splitting will occur Fragments which break off the fracture stump during nailing are probably due to incomplete fracture lines which were hardly visible on the first X ray picture (Figs 944–951) If the bone shows a considerable degree of bending, a fragment may break off on the convex side of the proximal fragment (Fig 483) Rieder has published a picture of this type

Breaking of the Guide Pin

Breaking of the guide pin has to date been reported only once Sprengell considers this incident due to a defect in the material. He introduced another thinner guide wire alongside the 9 cm piece that remained of the previous wire (Fig 192) and inserted the medullary nail over this The nail propelled the broken-off piece of the first guide wire past the fracture line without the nail itself reaching the fracture site (Fig 193) The broken piece of the first guide wire prevented a lateral displacement of the fragments To prevent angulation a hip spica was applied After 5 weeks callus formation on the medial side was evident as well as corrosion

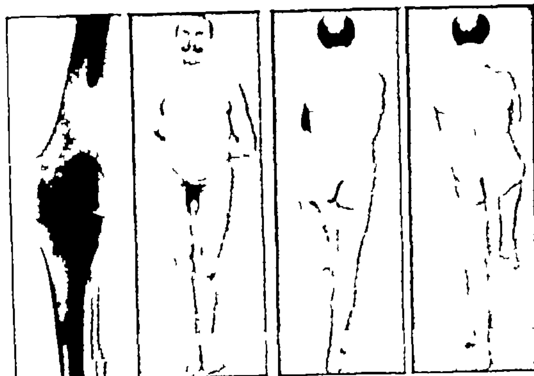


Fig 226 Fig 227 Fig 228 Fig 229

December 2 1941 June 10 1942

Fig. 226. Same as Figs. 222–225 6 weeks after injury

Figs. 227–229 The outward rotation of the knee joint is plainly visible when the feet are held parallel. When the knee and hip are flexed the left lower leg deviates inward

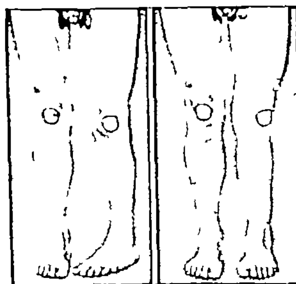


Fig 230 Fig 231

Fig 230 Photograph of a transverse fracture of the lower leg treated *elsewhere* with too short a nail and discharged after 3 weeks. During the subsequent weeks, the foot turned inward 45° and the fracture united in this position A transverse osteotomy was done, again a nail was inserted, and both fragments were united with a longitudinal wire loop as in Figs. 960–971 to prevent a new rotation.

Fig. 231 With both feet parallel, the patella points laterally



Fig 222 Fig 223 Fig. 224 Fig. 225
February 18, 1942 February 18, 1942

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If the medullary nail is too thick, fine cracks will be produced in the bone, as Küntscher has already shown but no actual splitting will occur Fragments which break off the fracture stump during nailing are probably due to incomplete fracture lines which were hardly visible on the first X ray picture (Figs 944–951) If the bone shows a considerable degree of bending, a fragment may break off on the convex side of the proximal fragment (Fig 483) Rieder has published a picture of this type

Breaking of the Guide Pin

Breaking of the guide pin has to date been reported only once Sprengell considers this incident due to a defect in the material He introduced another thinner guide wire alongside the 9 cm piece that remained of the previous wire (Fig 192) and inserted the medullary nail over this The nail propelled the broken-off piece of the first guide wire past the fracture line without the nail itself reaching the fracture site (Fig 193) The broken piece of the first guide wire prevented a lateral displacement of the fragments To prevent angulation a hip spica was applied. After 5 weeks, callus formation on the medial side was evident as well as corrosion



Fig. 238 Fig. 239 Fig. 240 Fig. 241 Fig. 242 Fig. 243

October 30 1942 November 24 1942 March 17 1943

Figs. 238 239 Same as Figs. 236 237 after removal of the first medullary nail and after insertion of a longer one The tip of the nail is 12 mm removed from the outer surface of the bone (arrow)

Figs. 240 241 Same as Figs. 238 239 4 weeks after the 2nd nailing Callus increased The nail did not migrate upwards. Its tip has approached the lateral wall to within 2 mm. (arrow)

Figs. 242, 243 Same as Figs. 232–241 after removal of the nail Firm union Where the tip of the nail touched the wall of the bone a cavity can be seen and the wall of the bone is thickened (arrow) Varus of 15 recurvation of 10

furthermore desirable to produce guide pins of more uniform thickness and not to produce them in such a variety of lengths

The Medullary Nail Slips off a Guide Pin Which Is Too Thin

Stotz described and illustrated a case in which the guide pin was well located in the distal fragment Because it was too thin, however, the medullary nail slipped off it and penetrated through the fracture onto the posterior surface of the distal fragment

Complications Due to Nails Which Are Too Thick

If the width of the medullary canal at its narrowest site and the curve of the bone are not measured accurately (see page 40) and if a nail is used which is too thick, it will be very difficult or even impossible to drive it to a sufficient depth But even the removal of it is sometimes very difficult or impossible if efficient instruments are not available A W Fischer reports a case with a far protruding nail admitted from another hospital For such incidents a hack saw (Fig 70) must always be on hand.

Ehrlich reported a case in which a separation of the fragments was caused by the use of a nail which was too thick. In spite of early weight bearing the fragments

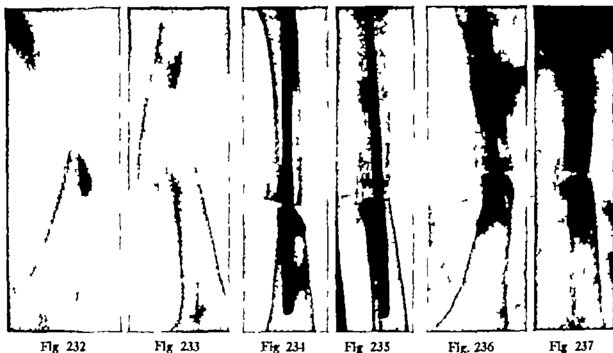


Fig 232 Fig 233 Fig 234 Fig 235 Fig. 236 Fig 237

August 12, 1942 August 28 1942 October 26, 1942

Figs. 232 233 Pseudarthrosis of the left femur developed elsewhere in a 67 year-old woman from excessive continuous traction which was used for 7 months. Marked decalcification.

Figs. 234 235 Same as Figs 232, 233 after transverse freshening of both fragments and medullary nailing elsewhere. The nail is too short.

Figs. 236 237 Same as Figs. 234 235 after 2 months. The woman was given a plaster cast from the ankle to the hip 14 days after the operation. Since the nail was too short, it had no hold in the decalcified bone, therefore the play of the fragments in walking caused it to migrate upwards in spite of the plaster cast.

on the fracture surface of the guide pin The bone united in good position The medullary nail was removed from above in the usual manner after six months. In order to remove the broken piece of guide wire, the bone was exposed and opened through a lateral incision.

Jamming of Too Thin a Guide Pin in the Guide Groove of the Medullary Nail

In our 59th femur fracture a thin guide pin was used and over this a 10 mm medullary nail was driven After it had penetrated about 15 cm it was not possible to drive it further The attempt to remove the guide wire which is usually very easy was equally unsuccessful With great difficulty we succeeded in removing the medullary nail together with the guide pin It was then evident that the wire which was too thin had through interposition of cancellous bone been partly forced out from the guide groove of the medullary nail and thus become jammed This made it impossible to drive the medullary nail further into the bone

Such incidents can be avoided if the guide wire and nail are tested every time before the operation It would be simpler yet if the guide groove were made so narrow that even a thin guide wire could not leave the groove It would be



Fig. 248 December 6 1941 | Fig 249 December 10, 1941 | Fig 250 | Fig 251 August 26 1942

Fig. 248 Same as Fig 24 after 22 days. The nail migrated 17 mm towards the knee, because in walking without the cast it was able to move in the bone

Fig 249 Same as Fig 248 after driving the nail in farther The head of the nail is now 47 mm. lower than in Fig 248 and has disappeared inside the bone. Was again discharged without supplementary plaster cast.

Figs. 250 251 Same as Figs 244–249 after 8 months, and 3 months after removal of the nail. Bony consolidation Good alignment in lateral view Varus of 10° in A P view because the lack of a supplementary cast permitted the bone to bend. Nevertheless no complaints at the present time All joints actively free Later joined the mountain troops without local discomfort. Since the proximal fragment was so short, it did not provide sufficient anchorage for the nail It would have been simpler and better to perform an osteotomy of the fibula to straighten the tibia and to apply a plaster cast without a medullary nail.

place where it should give the nail its main anchorage Any winch pulling in the long axis of the bone must be built very strongly Since a force up to 300 Kg is necessary for the extraction of freshly inserted medullary nails the winch must not rest against the bone but must be attached to the reduction apparatus Since the wires will always break when great forces are used a steel rod must be inserted transversely through the eye To this rod a sufficiently strong wire cable or chain can be fastened Since nails can rather easily be loosened by the concussion from blows it serves the purpose much better to use one of the three types of hammer extractors instead of a winch Even an ordinary nail can be removed with a pair of pliers only by prying and bending

Complications Due to Nails Which Are Too Short and Too Thin

In the beginning the opinion prevailed that penetration of the nail by 5–8 cm. into the distal fragment was sufficient This is true only if the fracture is located proximal to the isthmus of the medullary canal otherwise it is too short and does not



Fig 244 Fig. 245 Fig 246 Fig 247

November 13 1941 November 14 1941

Figs. 244 245 A 3-months-old compound transverse fracture of the tibia between proximal and middle third with valgus and recurvation of 7° each in a 17 year-old student, from a motorcycle accident. Slight callus formation. Treated *elsewhere* with excision and plaster cast for 14 weeks.

Figs. 246, 247 Same as Figs. 244 245 after closed medullary nailing Angulations corrected in both planes. Got up without a plaster cast after 8 days.

never approximated The gap of 15 mm was bridged by bone in the course of 5 months although the tip of the nail showed evidence of corrosion (Figs. 194–201) The final result was very good

Difficulties with Extraction of the Medullary Nail during the Operation

If a nail is too thick and cannot be driven in further, or if it becomes jammed in a curved bone an extremely dramatic situation may arise in which the nail cannot be removed at all or only with the greatest difficulty, after hours of strenuous efforts. Brücke A W Fischer Hart, Scanzoni Schneider and others have reported such incidents and I have had oral reports from many other sources

To avoid such distressing incidents the size of the medullary canal must be measured accurately before operation For the eventuality that the nail may become impacted suitable tools must be on hand for the extraction such as the extractor of Küntscher (Fig 71) Stör (Fig 83) and Pohl in connection with the clamp of Jörg Böhler (Fig 84) If even with these tools it is impossible to extract the nail, it must be sawed off with a hack saw (Fig 70) which must always be in readiness

The winch (Fig 79) is not suitable for the extraction of impacted nails Only loose nails can be removed with it and these can easily be pulled out with an extractor hammer Many authors have reported that the wires used with the winch broke repeatedly, even if doubled and tripled Furthermore the base of the winch digs itself into the bone next to the medullary nail and destroys the bone in the very



Fig. 256 Fig. 257 Fig. 258 Fig. 259

February 25 1942 February 25 1942



Fig. 260 Fig. 261 Fig. 262 Fig. 263

April 9 1942 March 7 1943



Fig 252 Fig. 253 Fig. 254 Fig 255

October 12 1941 October 18 1941

Figs 252 253 A 1½ year-old femoral fracture healed with varus of 20° antecurvation of 15 outward rotation of 20° and shortening of 3 cm in a 25-year-old teacher injured in a collision while riding in the side-car of a motor-cycle Treated *elsewhere* by wire traction with 14 Kg for 12 weeks then with a hip spica for 6 weeks

Figs. 254 255 Same as Figs. 252 253 after severing the bone with a Gigli saw and after nailing without removal of a wedge. The fracture gapes on the medial side. Got up after 2 weeks.

Fig. 256 Same as Figs 254 255 The bone bowed and the nail is also bent proximal from the fracture line, where it shows a crack in its lateral flange. Walked well until 2 days before.

Fig 257 X ray picture of the extracted nail shows an almost complete tear

Figs. 258 259 Same as Fig 256, after extraction of the broken nail and insertion of a new one. The angulations are corrected.

Figs. 260 261 Same as Figs 258 259 6 weeks after insertion of the new nail. The greater part of the fracture line is bridged by callus.

Figs. 262, 263 Same as Figs 258 259 6 months after removal of the nail, and one year after the second operation The bone healed with good alignment. Fracture consolidated. All joints free, no discomfort.

give sufficient immobilization Because the width of the medullary canal and the conditions of the spongiosa were little known before nails which were too short had frequently been used as is evident from the X ray pictures published in the literature A great number of complications were due to this circumstance viz angulation and shortening (Figs. 161–178 202–211 390–397) rotation (Figs 222–231), migration of the nail (Figs 232–251 and 1130) marked periosteal apposition (Figs. 390–397) and re fracture of the bone below the original fracture (see page 87)

All these sequelae can be avoided if nails of sufficient length and thickness are



Fig 256 Fig 257 Fig 258 Fig 259

February 25 1942 February 25 1942

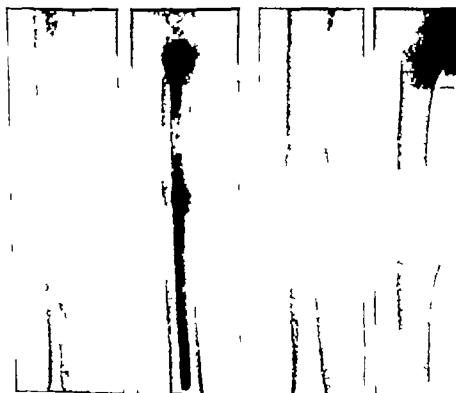


Fig. 260 Fig 261 Fig 262 Fig 263

April 9 1942 March 7 1943

used which are firmly anchored in the spongiosa of the metaphysis as shown in Figs 416–423, 478 693–696, 709, 710, 807–827, 874–883, 922–931 and 944–951 For this purpose the length and width of the medullary canal must be measured accurately (see page 40) If it becomes evident that a nail is too short, it should be exchanged early for one of sufficient length before trouble occurs.

Complications Due to Nails Which Are Too Long

Nails which are too long and penetrate into the joint always cause more serious disturbances than nails which are too short. If the course is aseptic, the joint must not be moved before the nail is removed, otherwise the cartilage will be damaged If, however infection sets in, the consequences are very serious because the inflammation creeps along the nail into the joint, leading to purulent arthritis with prolonged convalescence and ankylosis of the joint as shown in Figs 213–221 Infection of the joints, however, may even lead to loss of the limb or loss of life.

All these complications can be avoided if the required length of the nail is determined accurately before it is inserted and if after insertion of the nail, X ray pictures focused over the joint are taken immediately in both planes. If these show that the nail has penetrated too far it must immediately be retracted accordingly

Rotation of the Fragments

Küntscher was of the opinion that after medullary nailing the fragments cannot rotate against each other A W Fischer however, reported a femur in which marked inward rotation developed this was corrected by a transverse osteotomy after the nail was extracted. Another nail was then re inserted.

Rotation of the fragments is actually not an uncommon occurrence. It is usually due to nails which are too short. In this respect the case illustrated in Figs 222–229 with a fracture of the femur as well as of the lower leg on the same limb (both fractures at about the middle of the bones) is of particular interest. Since both nails were too short as well as too thin for these exceptionally wide medullary canals the knee with the adjoining fragments of the femur and the leg rotated outward whereas the foot retained its proper position in relation to the hip joint.

If only the femur or only the lower leg is broken, the foot with the distal fragment turns outward or inward (Fig 230)

This complication can be avoided if the conditions of the medullary canal are studied carefully before the operation and if a nail of sufficient length and thickness is used If open nailing is used rotation can be avoided by additional circular or longitudinal wiring (Figs. 709 710 940–951) In osteotomies, rotation can be prevented by dividing the bone obliquely instead of transversely

Migration of the Medullary Nail

Küntscher was of he opinion that the medullary nail is anchored so firmly that, in contrast to the hip nail it never migrates. In the meantime however several cases of migration of the nail have been reported by A W Fischer Rieder and others. This incident occurred more frequently in old cases than in fresh ones

(Fig 208) A W Fischer described a case in which the nail migrated into the knee joint below the patella without causing any further disturbances after its removal In every case the nail was too short and additional immobilization was inadequate or completely lacking In Figs 232-243, showing a pseudarthrosis of the femur, both fragments were freshened transversely elsewhere The medullary nail was too short and had no firm anchorage in the decalcified bone The supplementary plaster cuff was entirely inadequate in this large size femur The medullary nail migrated proximally into the vicinity of the fracture For such cases a nail must be used which reaches close to the joint and a supplementary wire suture must be used as in Figs. 709-712, or a hip spica must be applied as in Figs 771-783 The second medullary nail in Figs 238-241 is again too short Because a hip spica had been applied, the nail did not migrate but considerable angulation developed

In the 17 year-old patient of Figs 244-251, with an old transverse fracture of the tibia in the proximal third, of 3 months duration, with angulation and delayed callus formation, the nail migrated because no supplementary plaster cuff was used After the nail was driven deeper into the bone it disappeared within the bone and did not migrate any more. However, the part of the nail in the proximal fragment was too short to prevent a later angulation

In Fig 1103 the supplementary plaster cast was removed too soon

Migration of the nail can be prevented if nails of sufficient length and thickness are used and if in all fractures located outside the isthmus of the medullary canal, especially those with decalcified bones a supplementary wire suture is used or a plaster cast applied and left in place until the fracture shows firm bony union Sometimes the nail migrates into the bone (Figs 1038-1053), which may cause great difficulty in its removal In Figs 217 218, the nail migrated into the ankle joint.

Fracture of the Medullary Nail

Fractures of the nail have been observed on the femur (Figs. 252-263) lower leg (Figs. 430-441), humerus (Figs 468-479) and on the forearm (Figs 1172-1179 1186-1197 1210-1221) This occurred invariably in old fractures or pseudarthroses in which a defective operative technique caused delay in, or lack of, callus formation Since no supplementary plaster cast was used or because it was removed too early, motions at the fracture caused a continuous angulatory strain upon the medullary nail which finally led to its fatigue fracture The nail fracture reported by A. W Fischer occurred also in a case of osteotomy

In the femur fracture of Fig 256 with fracture of the nail Dr Engel proceeded in the following manner after straightening the leg with a Phelps-Gocht osteoclast (Figs. 934 E II/2746) and reducing the fracture in an apparatus (Fig 528) the original site of insertion of the nail was exposed through a small incision A guide pin the point of which was shaped like a crochet hook was re inserted into the guide groove of the nail As soon as the fluoroscope showed that the pin had penetrated beyond the tip of the nail it was turned 180° so that the hook on the end of the guide wire caught hold of the end of the nail In this way both fragments of the medullary nail were extracted without exposing the fracture site

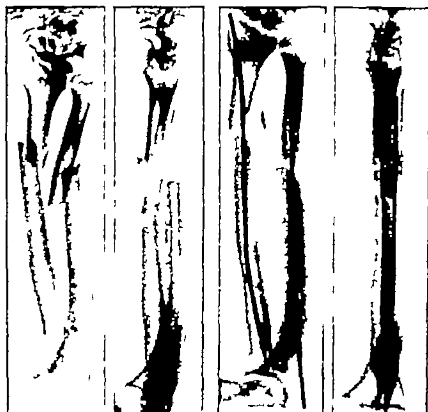


Fig. 264 Fig. 265 Fig. 266 Fig. 267

October 5 1943 November 3 1943

Figs. 264 265 Transverse fracture of both forearm bones in the distal third with lateral displacement, angulation, rotation and shortening, in a 26-year-old chauffeur injured in an automobile collision.

Figs. 266, 267 Same as Figs. 264 265 immediately after open medullary nailing which was performed 4 weeks after the accident with nickel-plated steel wires of 2 mm. thickness. Beginning callus formation at both fractures, because the fragments were overlapping. Treated *elsewhere*

This is the same operative plan as had been carried out for the fractured hip nail of Figs. II/1818–1829 and pages II/945–948 with the difference that in these cases the conditions were much simpler A new guide pin was then inserted into the old nail hole and over it a new nail was driven in As shown in Figs 258–263 bony union developed rapidly in very good position with full functional recovery

In the other 4 cases the fracture was exposed to freshen the ends On that occasion the fragments of the nail were removed.

Fracture of the nail can be avoided in osteotomies if the fragments are put in exact apposition, and in pseudarthrosis if the ends are freshened in order to avoid delay in callus formation the necessary supplementary support must not be removed too early

Radial Paralysis Caused by the Medullary Nail

Paralysis due to medullary nailing was unknown until Hart reported that, of 4 nailed fractures of the humerus, 2 developed radial paralysis following operation In one case the nerve was impaled by a large fragment which broke off during the operation In the second case the reduction was very difficult and required sharp

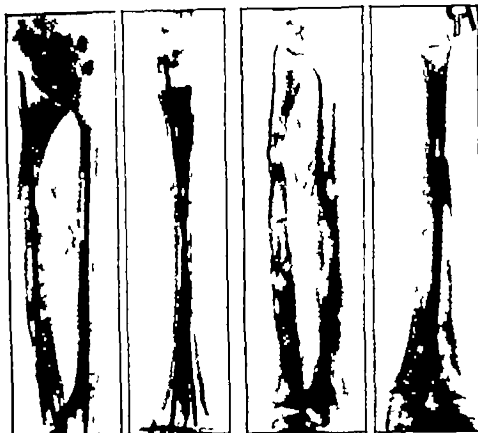


Fig. 268 Fig. 269 Fig. 270 Fig. 271
January 14 1944 February 16, 1944

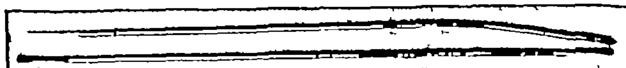


Fig 272

Figs. 268, 269 Same as Figs 266, 267 after 10 weeks. Large areas of decalcification within both bones and extensive periosteal appositions, due to corrosion Complains of drawing pains in the arm

Figs. 270 271 Same as Figs 266, 267 immediately after removal of the wires and 15 weeks after their insertion. Both bones show bony union in good position. The cavitation has decreased slightly the periosteal appositions increased. Three months later there was no rotation The other joints were almost free

Fig 272. Both wires show extensive corrosion.

angulation of the fragments Four weeks later the nerve was exposed and found lying in scar tissue adjoining the fracture After neurolysis the paralysis disappeared in both cases

Further observations about the occurrence of paralysis have not been reported to date

Refracture of the Bone with the Nail in Situ

Slany reported to me the following case A 38-year-old farmer was knocked down by a cow on March 31 1943 He suffered an oblique fracture of the right femur distal to the middle portion Next day he was hospitalized and nailed immediately



Fig. 273 Fig 274 Fig 275 Fig. 276

Fig 273 Area of absorption in the metaphysis caused by corrosion where the tip of the nail shown in Fig 274 was located.

Fig. 274. Corroded medullary nail of Fig 273

Fig. 275 Extensive corrosion effect on the medial side of the femoral shaft and considerable absorption along the entire nail track.

Fig 276 Corroded nail of Fig 275 Figs. 273–276 are Sprengell's observations (Zbl f Chir No. 7 1942)

Great force was needed to insert the nail because the cavity was somewhat too narrow for the 10 mm nail. The position of the fragments was excellent. From the proximal fragment a piece 5 cm long broke off the antero medial surface, also posteriorly a wedge with a 2 cm base. The medullary nail was too short. It reached to within 9 cm of the joint. After 14 days the patient got up and was discharged from the hospital with a knee motion of 180–90° After 6 weeks he was able to walk with a cane On June 15 (the 11th week) he slipped and fell There upon he had such severe pain in the thigh that he had to stay in bed for a few days. The X ray pictures showed an oblique fracture on the medial side of the distal frag ment without displacement. Since the nail was too short it could not prevent a torsion fracture in the distal fragment However the force was not strong enough to produce a displacement.

Corrosion Damage Caused by the Medullary Nail

Sprengell was the first to describe and publish pictures of corrosion damage to the bone (Figs. 273–282) This occurs if the material used is not definitely corrosion



Fig. 277 Fig. 278 Figs. 279–282

Figs. 277 278 Fracture of the femur with nail and longitudinal wire suture The entire bone is covered with periosteal appositions.

Figs 279–282. Photographs of the nail of Figs 277 278 with 2 extensive areas of corrosion. The X ray pictures do not show these corroded areas because of overlapping projections.

proof Its effect was also observed by A W Fischer, Rieder Stör and others The best material is austenitic chrome nickel steel with 18 per cent chromium and 8 per cent nickel The V 2 A-steel of Krupp is an example of this type of metal If the nickel content is too low as in the martensitic steels rusting and corrosion occur quickly (Figs. 273–282 and II/1802–1806) For further details about this see pages II/898 899 and Stör, Der Chirurg ', No 11, 1943 The rust destroys the surrounding bone tissue and the bone may break in this region if the nail is not removed in time On the outside of the bone surrounding the rust-damaged area, periosteal appositions can always be noted which reinforce externally the internally weakened structure of the bone (Figs 198 199) In some cases however pseudarthrosis develops In the presence of corrosion patients usually complain of "drawing" pains especially during the night (pages II/938 939) Sometimes sinuses develop from the presence of rust With nailed hips one can frequently observe that the granuloma caused by the rust weakens the femoral head to such an extent that it collapses (Figs II/1780 1801 and II/1839–1841) This proves that the damage to the bone tissue is caused merely by chemical and not by mechanical processes and that it can be prevented by the use of proper material Systemic damage caused by large quantities of embedded V 2 A-steel in the body is described on pages 52 53

THE CALLUS PROBLEM

The fundamental laws of fracture treatment are

1 Reduction
2 Retention of the well reduced fragments in good position until they are firmly united.
3 Exercise

The general and local impairment of the motor apparatus and of the circulation caused by the injury as well as by the immobilization will be less, the quicker bony union occurs, i e , the faster the callus forms and consolidates It is therefore extremely desirable to find some means of speeding the formation of callus and thus shortening the period of immobilization All chemical, physical or biological means for this purpose recommended to date have proven entirely ineffective I therefore received with great enthusiasm Küntscher's announcement that his nail does not only immovably retain the fragments but also produces a marked stimulation of the callus formation Unfortunately he was in error

Because many misconceptions about the formation of callus and its disturbances prevail, I will try to rectify these and will devote to the purpose a special chapter with many illustrations

Essentials of Reduction and Retention

There are 5 types of displacements viz

1 Angulation (dislocatio ad axim)
2 Rotation or torsion of the fragments against each other (dislocatio ad peripheriam)
3 Lateral displacement (dislocatio ad latus)
4 Longitudinal displacement with shortening (dislocatio ad longitudinem cum abbreviatione or contractione)
5 Longitudinal displacement with lengthening (dislocatio ad longitudinem cum elongatione or distractione)

The latter displacement was unknown except in fractures of the patella and of the olecranon and of avulsed fractures of ligamentary and muscle attachments be cause it hardly ever occurs in shaft fractures as a result of the accident. Since the introduction of skeletal traction, however it has become of paramount importance. In shaft fractures distraction is, as a rule not due to the accident, but to the treat ment. It is the most dangerous and gravest of all displacements because the frag ments frequently will not unite if they are kept separated for many weeks or months. That separated fragments will not unite was known to *Hippocrates* from the fracture of the patella. If the gap between the fragments is only minor bony union may occur but only after a long time

In the treatment of fractures the goal was always to prevent undesirable sequelae Next to lack of bony union the sequela mentioned first was shortening then angulation rotation decalcification of the bones atrophy of the muscles, limitation of motion and painfulness of adjoining or further removed joints and prolonged swelling

Shortening angulation and rotation are sequelae of fractures only, the other sequelae may follow other injuries as well The displacement of fragments can be removed permanently by timely reduction and suitable retention Reduction must be carried out with a plan Angulation and rotation are corrected first In transverse fractures the lateral displacement can only be corrected after the shortening has first been eliminated by traction and counter traction causing a slight distraction, otherwise the jagged fracture surfaces cannot be moved upon each other (Figs 534 535) As soon as the fragments are in position, longitudinal traction must be decreased until the fracture surfaces touch each other After medullary nailing they must be impacted (Figs 536–539) Therefore distraction of the fragments must only be produced temporarily for the purpose of reduction *After lateral displacement has been corrected, any lengthening must immediately be eliminated*

The correction of lateral displacements is very important in joint fractures and in para articular fractures This is, as a rule, not difficult and with proper immobilization redisplacement is not very likely In shaft fractures however, it is sometimes difficult to correct the lateral displacement which has a marked tendency to recur Many see in X ray pictures merely the lateral displacement and make every effort to eliminate it This is the reason why so many closed fractures are treated operatively Others apply lateral traction or pressure pads and frequently overlook the fact that at the same time they maintain a separation of the fragments by continuous traction transfixion or a plaster spica This means that they corrected angulation, rotation, shortening and lateral displacement but at the same time produced another displacement, the most dangerous one, viz a distraction of the fragments *Yet, a lateral displacement, even by full shaft s thickness is entirely insignificant cosmetically as well as functionally in shaft fractures provided no angulations, no rotation and no appreciable shortening are present at the same time* as shown in Figs I/196–203, I/206–215 and II/2016–2026 **Distraction (lengthening) is the most dangerous of all displacements It must be corrected immediately after reduction and during the period of retention it must be avoided under all circumstances**

Callus Formation without Medullary Nailing

Callus is developed by the bone in response to a stimulus which is strong enough to break the bone A fracture is therefore the prerequisite for callus formation All tissues in the region of the fracture area are involved, viz the bone marrow, the bone itself the periosteum and the surrounding tendons and ligamentary attachments as well as the muscles The hematoma mixed with the fat of the bone marrow and the small bone splinters acts as the stimulus as well as the reconstruction material *The most important requirement is good general and local circulation* The severance of nerves has no influence upon callus formation nerve stimulation, however can markedly impair it Even psychic influences and their effect upon the circulation must not be underestimated (see pages I/20 and II/1520 II/1536) Joy increases the rate of the pulse

The process of callus formation varies greatly in various bones and various sec

tions of one and the same bone with the patient's age and with his general condition, and with various nutritional and climatic circumstances, but it always follows a rule Young people form callus more quickly than older people. Bones which are surrounded by a thick cuff of muscles and are therefore well nourished produce callus quickly, in intra articular fractures, e g those of the neck of the femur or of the scaphoid of the wrist it is formed slowly and sparsely Special features of the callus formation in metacarpal and metatarsal fractures have been pointed out on pages I/725 and II/1473 One must be acquainted with these circumstances so as to avoid superfluous or even injurious measures

Absorption at the fracture stumps After any fracture a marked hyperemia of the fracture area develops and lively anabolic and catabolic processes take place. Both fracture stumps become necrotic, as can be proven histologically, for a distance of 1–2 mm on the neck of the femur sometimes up to 2 cm As a rule, the thicker the bone, the more of it will be absorbed F König has devoted special studies to these processes This dead tissue is dissolved and absorbed and acts biologically as a stimulus upon its surroundings From a mechanical standpoint, however this process is of the greatest importance because even in fractures without displacement it produces a gap between the fragments which must later again be filled The development of this gap can best be followed in *fractures of the carpal scaphoid* The fracture line may originally be so faint that it can hardly be distinguished on the first X ray pictures (Fig I/1253) After 10–14 days the absorption along the fracture surfaces has progressed sufficiently to be plainly recognized by a widening of the fracture line If this fractured bone is then immobilized properly, the gap is usually filled by bone in about 6 weeks If it is not immobilized, the absorption continues and a traumatic cavity develops as shown in Figs 487 488 E, I/249, I/1264, I 1269 and I 1270 If even then no immobilization is instituted, both fracture surfaces become sclerosed and a pseudarthrosis develops (Figs 493, 494 E, I/1273 I/1274) and sometimes a necrosis of one or of both fragments occurs (Figs. 495 496 E I/1275 I 1276)

In shaft fractures the absorption transformation and reformation of bone follows an entirely different pattern This can best be studied by observing the healing of *fissured fractures of the second and third metatarsals* In these fractures the fracture line is likewise at first so faint that it can barely be seen with a magnifying glass (Figs 1024 E II 2994) After 2–3 weeks the line becomes wider and more plainly visible If these fractures are immobilized by a walking cast they unite in 6 weeks by the formation of a comparatively slight periosteal callus which surrounds both fragments like a vise while the fracture line in the bone is still distinctly visible (Fig II 2993) These fractures are frequently not recognized and are therefore not immobilized Some omit immobilization intentionally in order to apply massage and passive motion Under these circumstances, an extensive periosteal irritative callus will develop (Figs 1026 E II 2996) which will not recede before ½–1 year (Figs 1027 E, II 2997) The foot then remains swollen and painful for many months as an indication of disturbed circulation The healing process is therefore much

different in these cases from the healing of the carpal scaphoid, because the metatarsal bones have a strong periosteum and are surrounded on all sides except on the dorsum by well vascularized muscles The scaphoid, however, is more than half covered by cartilage and no muscles cover the periosteum

In *fractures of the shaft of the ulna alone* with dislocation of the proximal end of the radius, the fracture ends also undergo absorption Since the ulna is thicker than the second metacarpal bone, the absorbed area is larger With good reduction and perfect apposition of the fragments, a gap of 3–4 mm develops after 3–4 weeks since the fragments cannot approximate each other If the dislocation of the intact radius has been reduced (Figs I/864–867) In this fracture, usually strong periosteal callus develops on both fracture stumps which, however, is frequently not able to bridge the gap even with adequate immobilization for 8–12 weeks, so that pseudarthrosis develops (Figs I/868–871) If in this type of fracture dislocation the radius is not reduced or if it redislocates as in Fig I/875, the fragments can approximate each other and bony union will take place if the fragments are properly immobilized for a sufficient length of time, that is, 8–12 weeks If, however, the fracture is not immobilized and massage and passive motion are applied instead, a pseudarthrosis will develop on the ulna even if the dislocation of the radius persists (Figs. 1172–1179, 1186–1197)

If both forearm bones are broken and well reduced and if they are immobilized long enough, i e , 10-12 weeks, the radius usually develops bony union first It then acts as a prop to the ulna and it may take 2–3 years until this fracture consolidates through a stage of pseudarthrosis (Figs I/916–926, I/962–973)

For an *isolated transverse fracture of the radius*, the conditions after reduction are much more favorable because the distal fragment can approximate the proximal fragment by a subluxation in the distal radio-ulnar joint (Figs 407–410, 411–414 E, I/1002–1009, I/1010–1015, I/1016–1023, I/1024–1027 I/1028–1030)

If the approximation of the fragments is prevented by an incorrectly applied double wire transfixation cast (Figs 395–400 E, I/936–941) or by a Lane plate following transverse freshening of the fragments, callus will not form (Figs I/1051–1054) This same patient, however, developed bony union following Z-shaped freshening and circumferential wire suture (Figs. I/1055–1058) The cause of non union in this case lay not in the bone or in the patient but in the method of immobilization

As long as the belief prevailed that the medullary nail stimulates callus formation, even fresh transverse fractures and pseudarthrosis of the forearm bones were treated with it Since the nail for the radius is always curved, it prevents an approximation of the fragments as absorption takes place and therefore, even with this method, pseudarthrosis developed frequently (Figs. 1117–1126 1204–1209, 1210–1221)

In *transverse fractures of the tibia* alone the area of absorption at the fracture ends is proportionately wider than on the ulna, the gap should therefore become wider However the fragments can approximate, similar to those of the radius, by slight central subluxation in the lower tibio-fibular joint The fracture line is usually still plainly visible after three months and the periosteal appositions at the



Fig. 283 Fig 284 Fig. 285 Fig. 286
March 13 1944 March 13 1944

Figs. 283 284 A 16-day-old fracture of the right femur at the middle of the shaft with shortening of 5 cm. in a 26-year-old man, from a motor-cycle accident on February 26, 1944. Was provided with a plaster cast after 2 days. Extensive cloudy callus formation 16 days after the accident.

Figs. 285, 286 A 30-day-old fracture of the left lower leg above the middle with shortening of 4 cm. Also fracture of the fibula above the middle and below the head, in a 29-year-old man, from an airplane crash on February 14 1944. Was provided with a padded cast 2 days after injury Good callus formation 28 days after the accident.

fracture ends have not yet achieved contact (Figs II/2472–2475) After 6 months one may often gain the impression that a pseudarthrosis is developing (Figs. II/2476 2477) The callus has become stronger but the fracture line continues through it and the ends appear sclerosed As a rule however, full consolidation occurs after one year (Figs. II 2478 2479) If however, the intact fibula which holds the tibial fragments apart is osteotomized early the fragments can approximate each other as absorption takes place and they will then frequently unite firmly in 10 weeks, since the development of callus is not interfered with by gaping (Figs. II/2480–2485)

Transverse fractures of the femur show bony union in 8–10 weeks and *transverse fractures of the humerus* unite firmly in 4–6 weeks after reduction without distraction Healing is more rapid if the fragments are not in perfect apposition, but displaced laterally by at least one half of the thickness of the shaft (Figs I/733 734) Union occurs promptly too if the fragments overlap with a shortening of at least a few millimeters.

That a slight hiatus between the fragments is sufficient to delay callus formation by many months is evident in fractures of the fingers (Figs. I/1477–1486 I/1447–



Fig. 287 Fig 288 Fig. 289 Fig 290

April 1 1944 March 20 1943

Figs. 287 288. A 17-day-old compound fracture of the left humerus with paralysis of the radial nerve, without infection, with shortening of 4 cm., in a 30-year-old man, from a rifle shot on March 13 1944 Was provided immediately with a Desault bandage. Pronounced callus formation 17 days after the accident.

Figs. 289 290 A 6-months-old infected gunshot fracture of the humerus shown during application of a plaster cast, in a 22 year-old man from shell-fragment on September 14 1942 Was treated for 10 weeks with wire traction through the olecranon with a weight of 5 Kg Crown sequestra at both fracture ends. No callus formation.

1451), of the toes (Figs II/3008–3012), or in avulsion fractures of the 5th metatarsal (Fig II/3016)

Oblique fractures develop union rapidly with very little visible periosteal callus formation even if the fragments had been exposed operatively and united with large metal foreign bodies, provided accurate apposition and good retention was obtained (Figs 922–931, 940–943 944–951) In transverse fractures of the tibia, however, the large foreign body delays callus formation even if the fragments are in perfect apposition and even if the locking action of the fibula is completely eliminated by osteotomy or even by resection of a large segment (Figs 952–959, 960–971) From this we must draw the lesson that in operative procedures the freshening of the fragments must never be done transversely but always obliquely or Z-shaped

In oblique fractures with no contact between the fragments and with shortening prevented as in fracture dislocations of the forearm near the elbow (Figs 381–382 E, I/872 873) only faint callus develops. Complete consolidation of the ulna takes many months (Fig I 874) In spiral fractures with a slight shortening of 3–5 mm

e g , of the lower leg, healing is rapid (Figs II/2394–2401, II/2402–2409) Callus is then rather faint, yet fit for weight bearing If immobilization was not interrupted, periosteal callus can barely be discerned

In spiral fractures in any third of the femur, bony union with hardly any periosteal apposition develops within 8–10 weeks even if the fragments are displaced laterally by full thickness of the shaft (Figs. II/1984–1986, II/2016–2021) It is therefore not necessary to correct a displacement by full thickness of the shaft under all circumstances, because healing takes place as a rule just as quickly as with perfect apposition (Figs. II/1987–1990) provided no distraction exists.

It is again and again apparent that even in oblique fractures no callus forms if the bone is lengthened by *excessive* traction even if only by a few millimeters, although the fracture surfaces are still in apposition for a stretch of 5–10 cm without appreciable lateral displacement If traction is then reduced, a shortening will occur in lower leg fractures which may yet be followed by bony union (Figs II/2390–2392) provided the fibula has not yet united In transverse fractures in which a large hiatus was produced by *excessive traction,* union usually does not occur

Rapid callus formation with shortening and overriding of the fragments Callus forms more quickly and abundantly the greater the shortening, if the fragments were immobilized completely and continuously without ever having been separated by excessive pull. This is most clearly evident from the X ray pictures of two femur fractures (Figs. 283 284 291 292) one lower leg fracture (Figs 285, 286) and one humerus fracture (Figs 287, 288), which distinctly show cloudy callus formation in the 3rd or 4th week These patients had moreover, undergone a strenuous transport for over 1000 kilometers The same observations can be made, however, in patients in good general condition under favorable external circumstances (Fig 373) It is of particular interest that with shortening and good immobilization, callus forms rapidly even if displacement by full shaft thickness or even by double shaft thickness persists as shown in Figs I/196–203 and Figs 307–316 The patient of Figs 307–316 is of particular interest because callus formation was only faint on the side with the lesser shortening but marked on the side with the greater shortening

Influence of muscle interposition upon callus formation If shortening exists muscle interposition is as a rule of no significance If however, the fragments are separated longitudinally callus formation stops (Figs 305 306) not because of interposition of muscle tissue but because of the longitudinal separation of the fragments.

If the fragments overlap and are in contact (Figs. 291 292), callus forms around both fragments If the fragments are not in contact callus forms in fractures of the middle of the femur at the distal fragment growing proximally whereas no callus whatever appears on the proximal fragment which also never becomes sclerotic (Figs 299 300 and 307–311) In such fractures the medullary canal of the proximal fragment is still open after years. Extensive sclerosis of both fragments develops only in contact pseudarthrosis (Figs. I 234–236 952–959)

As soon as the fragments are reduced and immobilized, e g with a medullary nail, callus forms chiefly on the medial and posterior circumference (Figs. 293 294)

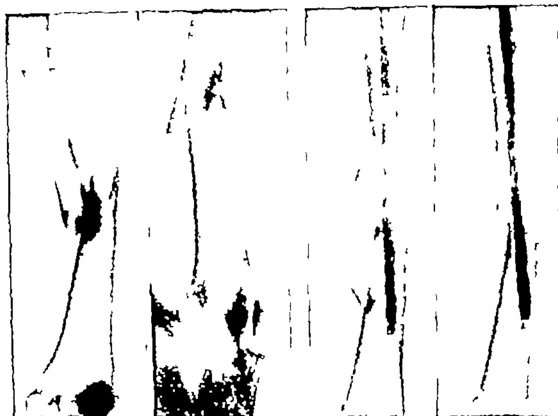


Fig. 291 Fig 292 Fig 293 Fig 294

March 5 1942 June 1 1942

Figs. 291 292. Leverage fracture of the left femur in a 23-year-old blacksmith who was run over Provided immediately with a plaster cast After 5 weeks following the accident there was a shortening of 4 cm., varus and recurvation of 20° each, extensive and strong callus all around the fracture which is still somewhat springy It was exposed and provided with a medullary nail.

Figs. 293 294 Same as Figs 291 292 12 weeks after operation The nail is too short therefore, the fracture healed with varus and antecurvation of 10° each. Strong callus formation on the medial and posterior side.

but not because these are the concave sides, but because the muscles are attached to them Callus formation in the tibia illustrates this best here the callus forms not on the concave medial and anterior aspect but chiefly on the lateral and posterior side along the interosseous membrane (Figs. 816–823)

Since bone absorption of 1–3 mm occurs in all fractures, it is one of the chief objectives of fracture treatment to obtain a shortening of 1–10 mm , in order to prevent a diastasis between the fragments which would cause a delay in callus formation as well as serious circulatory disturbances and their sequelae

Excessive Callus Formation without Medullary Nailing

This occurs under various circumstances for instance, if well vascularized fragments in good apposition are continuously subjected to slight angulatory stresses, such as the faint fissure fractures of the 2nd and 3rd metatarsals (Figs 1026, 1027 E, II 2996 2997) fractures of the distal half of the femur (Figs. 396–407) or of the humerus (Figs 1010–1063) which were treated with the medullary nail Such callus is loose and abundant but for a long time unfit for functional use and also painful



Fig. 295 Fig. 296 Fig 297 Fig 298

Figs. 295–298. Specimen and X ray pictures of an infected fracture of the femur proximal to the knee joint. Extensive, irregular partly scaly periosteal appositions which gave the callus a fuzzy appearance in the X ray pictures, as in Figs. 324 and 675–678.

Excessive callus formation is also seen in fractures close to joints surrounded by short fibred muscles which only bridge one joint, as at the proximal end of the femur and at the distal end of the humerus if the fractures are not properly immobilized whereas with good reduction and immobilization, callus of normal size develops also in these fractures. In lateral fractures of the femoral neck which are not well immobilized luxuriant callus formation arising from the distal fragment, and pseudarthrosis developing on the proximal fragment, may be found simultaneously

Excessive callus formation with extensive periosteal appositions is most frequently found in compound fractures especially in gunshot fractures, in case infection sets in This constitutes a tremendous stimulus if the fragments are not separated The bone then shows thick, 'fish scale like appositions (Figs. 295, 297 and 671–678) In spite of the abundant callus these bones are for a long time not firm enough for functional use

If the fragments overlap and are angulated callus will develop in fractures of the middle third of the femur only on the distal fragment, whereas the proximal fragment protrudes into the surrounding tissues without the slightest evidence of callus formation As a rule the medullary cavity of this fragment does not become operculated by sclerosed bone as in pseudarthrosis but remains open (Figs. 299, 300 307–311) because there is no counter-pressure as in contact pseudarthrosis, in which both ends are operculated (Figs I 234–236 and 952–959)

The Sequelae of Excessive Continuous Traction

With splints and plaster casts it was formerly not possible to prevent shortening in many fractures especially those of the femur It was therefore the goal of all

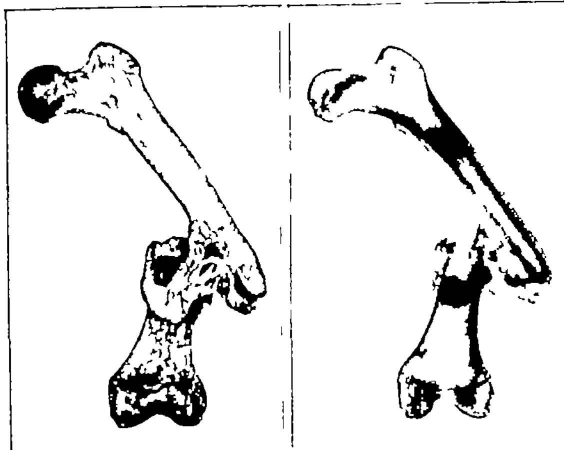


Fig. 299 Fig. 300

Figs. 299 300 Specimen and X ray picture of an infected fracture of the femur healed with marked angulation. In fractures with such pronounced angulations, the callus usually develops from the proximal end of the distal fragment, whereas no callus forms at the end of the proximal fragment, so that the medullary canal remains open, as in Figs 313–316

surgeons to find some way to prevent shortening by continuous traction Slings or cuffs fastened above the knee or ankle were tried repeatedly without success, because the required pull caused unbearable pressure and serious damage Not until adhesive plaster was introduced was it possible to exert sufficient traction But the application of adhesive traction was difficult, blisters dermatitis and pressure sores developed frequently Therefore the method of applying traction directly to the bone by means of pins, calipers or wires was greeted with enthusiasm This skeletal traction is capable of outstanding achievements when used properly, and any shortening can be overcome with it It entails however the danger of infection (see pages II/838–847), and again we always see cases in which lack of proper supervision led to serious infection and even death These complications can easily be avoided if the pins or wires are carefully watched and removed immediately upon the appearance of inflammatory reactions However, complications caused by **excessive traction** are much more common because this *leads to separation of the fragments, serious circulatory disturbances delayed callus formation or non union wasting of muscles, decalcification of bones and limitation of joint movement* Occasionally even paralysis may occur (Figs 322–333)



Fig. 295 Fig. 296 Fig. 297 Fig. 298

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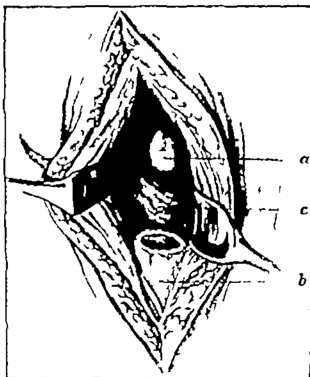


Fig 305 Fig. 306

May 28, 1930

Fig. 305 Fracture of the left femur with marked diastasis of the fragments, probably due to excessive traction 18 months after the accident.

Fig 306 Sketch to Fig 305 drawn during operation Massive interposition of muscle tissue. (a) Proximal fragment (b) Distal fragment (c) Interposed muscles. Both pictures are taken from the book of Fritz König, "Operative Behandlung der Knochenbrüche.

and cellular exudation, a sprouting of capillaries to an increase in connective tissue and eventually to formation of granulation tissue. Decreasing peristatic hyperemia leads gradually to healing in which various degrees of vasomotor stimulation cause certain definite tissue formation. The highest degree of peristatic hyperemia causes formation of granulation tissue, a medium degree causes an increase in fibrous elements with simultaneous reduction of the already formed cellular elements, the connective tissue cells and capillaries Further reduction transforms for example in a fracture the fibrous tissue into cartilage and eventually into bone. The specificity of the mother tissues plays a *determining role in these processes*

"Any injury will heal the sooner the quicker the condition of stasis due to maximum stimulation of the circulatory terminals or a high degree of peristatic hyperemia is reduced to normal. The course of these stages is the sole determining factor *in the healing process* "

Lexer demonstrated the fracture hyperemia in over riding fragments It would be most instructive if similar injected specimens were produced from *fractures in* which the fragments had been continuously distracted.

Excessive traction does not permit the stimulus to subside Circulation is therefore poor throughout the fracture area regenerative power is poor, hence the transformation of connective tissue into cartilage and bone does not take place

The consequences are

Delayed callus formation frequently leading to

Formation of eburnated mechanically inferior callus bridges and therefore

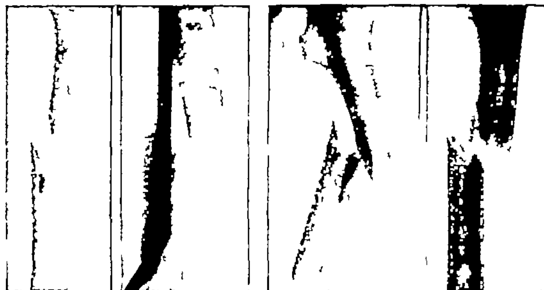


Fig 301 Fig 302 Fig. 303 Fig 304
May 14 1942 August 13 1942 October 31 1942

Figs. 301 302 Fracture of the left femur under continuous traction in a 21 year-old musician 165 cm. tall, weighing 62 Kg injured on March 23 1942 Wire traction was applied to the femur *elsewhere* 2 days after the accident with a weight of 10 Kg. The fragments have separated by 10 mm. Although 7 weeks had elapsed since the accident, no trace of callus was formed because of the excessive traction.

Fig 303 Same as Fig 301 after another 3 months. Traction was removed 4 months after the accident. This was followed by angulation and shortening Small callus clouds at both fragments.

Fig 304. Same as Figs 301 and 303 7 months after the accident. Because of the angulation and shortening another wire traction with 7 Kg was applied *elsewhere*. Angulation and shortening corrected. Only slight callus formation. Fracture entirely loose. Thereupon, freshening and medullary nailing which was followed by comparatively rapid bony union.

It is surprising to notice again and again that a slight separation of the fragments in the long axis by only a few millimeters, is usually sufficient to delay the formation of callus as shown in Fig 376 or to prevent it completely as in Fig 301, whereas lateral displacement with shortening does not usually interfere with callus formation (Figs 307–311) This is probably due to an irritation of the vascular nerves by the *abnormal tension* leading to vasospasm, as propounded by Ricker Victor Schäfer clearly explained Ricker s investigations as follows

The stimulation of the vascular nerves causes a reflex closure of the arterioles and by the dilatation of the capillaries and smallest veins a stoppage of the circulation occurs in the second zone (see page I/107) of the wound area which includes the fracture Tissue affected by continuous stasis is without nourishment and therefore becomes necrotic. In the area surrounding the wound i.e the third zone the stimulation of the nerves is less. The smallest arteries are here not completely closed but merely contracted to a very narrow lumen whereas the capillaries and small veins are markedly enlarged as in stasis For this reason the blood supply to the area, although it appears markedly hyperemic, is actually less, because the blood flow is much slower since it passes through contracted arteries into dilated capillaries and venules—much the same as a stream which slows down when it enters a wider bed. Ricker calls this condition of the circulatory terminals a peristatic hyperemia because it precedes or follows as a rule the maximum degree of vasomotor stimulation, viz. stasis. This marked degree of peristatic hyperemia leads to serous

A true physician will weigh all circumstances in every individual case and plan his treatment accordingly In fresh closed fractures the aim must be to keep shortening and angulation to a minimum, and to strictly avoid the slightest distraction A fracture healed with angulation should, however, not be corrected in patients over 40 years of age because the risk is too great Particular caution must be exercised in infected fractures, because refracture and strong traction usually lead to a flare up of the infection and marked suppuration The ensuing sequestration of small fragments which were already in the process of uniting will increase as the gap between the fragments is widened (Figs 289, 290) Muscles are frequently destroyed by tubular abscesses The fracture heals very slowly if at all The limb must be kept in a plaster cast for many months, and the joints stiffen It can even happen that the flare up of the infection is so severe that the member must be amputated, or that the patient dies Under such circumstances it is much preferable to forego an attempt to correct the shortening and thus to preserve life and limb and to restore comparatively good function in a fairly short period of time If a femur heals with a final shortening of more than 4 cm, the leg can be equalized safely in younger patients by shortening the well femur using a medullary nail (Figs 705–734)

The number of patients who of late were seriously damaged by excessive skeletal traction far outnumbers those who were damaged by operative procedures with exposure of the fracture site. I therefore welcome the treatment of closed femoral shaft fractures with Küntscher's medullary nail because these cases thus escape the dangers of improper continuous traction

Since wire traction is now used extensively and frequently quite injudiciously, the overall results of fracture treatment have not improved since its introduction, but have become worse and the healing time now takes as many months as it formerly took weeks

Delayed Union and Non union through Excessive Continuous Traction

In order to avoid the damages resulting from excessive traction it is necessary to determine accurately the strength of the required pull for each individual case

Determination of the Weight for Skeletal Traction The problem of the treatment of a fracture is not solved by merely applying some kind of weight or by pulling as hard as possible On the contrary traction must be adjusted very accurately for each individual case and the effect of it must be checked roentgenologically and with a tape measure not more than 2–3 days later, in order to increase or decrease the weight as required One must know that a shortening of 1–2 cm is, as a rule entirely irrelevant, whereas a lengthening of 0.5–1 cm will always unduly prolong the treatment and frequently cause serious transient or permanent damage If too little weight is used the shortening will not disappear and if too much weight is used the fragments will separate (Figs. II/1603 II/1976 II/2159–2164 and 322–357) Both conditions cause pain in the beginning

The amount of traction required is determined by the development of the muscles which can be estimated by inspection and palpation and from the body weight

Refracture or

Pseudarthrosis

I operated upon hundreds of pseudarthroses Most of those of the femur and lower leg were due to excessive continuous traction (Figs. II/2159–2164, II/2596–2605, 735–783 and 940–971) I have repeatedly pointed out these complications (see pages II/1064 and II/1286 and in many other places)

If traction is extraordinarily excessive and is maintained for a long period as in case 4 (Figs 322–333), case 5 (Figs. 334–343), case 6 (Figs. 344–351), case 7 (Figs. 352–357) and in Figs 358–365, 366–372 and in Figs II/2390, 2391, not only will local disturbances ensue but severe vasomotor complications in the entire limb as well. The consequences are

Cyanosis and coldness of the limb

Tendency to swellings

Marked muscle atrophy Especially the small intrinsic muscles of the foot waste rapidly and shorten, causing claw contracture of the toes.

Contracture of ligaments, causing stiffness of joints

Rapid decalcification of the bones This causes pains in the limb and is followed by

Shrinkage of the skin, and glossiness of the skin

Shrinking of the affected hand or foot, even in adults

The symptom complex is that which follows a light degree of acute ischemia.

Very strong traction is sometimes followed by paralysis of the peroneal or sciatic nerve.

In *compound fractures* excessive traction, by adding further injury to the tissues, causes, in addition to the circulatory disturbances

marked inflammatory reactions

abscesses and

sequestration of bone splinters which were already in the stage of healing in Not uncommonly

crown sequestra on both fracture ends appear (Figs 289 290)

For these reasons continuous traction must be used with particular caution in old compound fractures or in infected fractures.

I know a surgeon whose first thought in all gunshot fractures was the elimination of shortening and angulation irrespective of the general condition of the patient or of the wound situation. He achieved his purpose in many cases. In some he obtained a lengthening However the excessive traction frequently caused marked inflammation It frequently took 8–12 months occasionally even longer to achieve bony union whereas without excessive traction, union sufficient for functional use would have taken place in that many weeks The extraordinarily prolonged immobilization caused marked restriction of motion in all joints, the muscles were weakened and the walking ability was permanently greatly impaired. The result was therefore, much worse than in those cases which healed with some shortening and angulation.

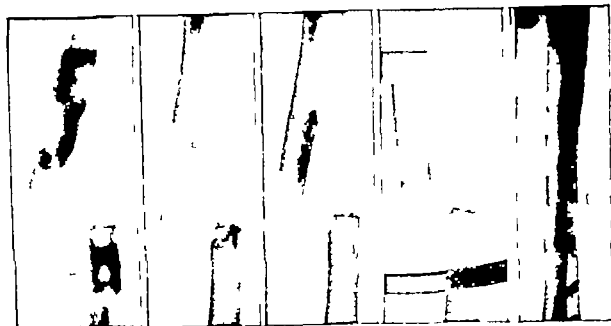


Fig. 312 July 31 1942 — Fig. 313 August 4 1942 — Fig. 314 August 10 1942 — Fig. 315 August 17 1942 — Fig. 316 Sept. 15 1942

Fig. 312. Leverage fracture of the left femur distal from the middle in a plaster cast, 17 days after injury in a 19 year-old man injured on July 14 1942 Simultaneous dislocation of the left hip with paralysis of the sciatic nerve and fracture of the right femur (Fig 307) Because the posterior dislocation at the hip joint had not been recognized and was not reduced, the proximal fragment is adducted and the distal fragment is atypically displaced laterally and abducted by more than twice the width of the shaft. Shortening 1 cm.

Fig. 313 Same as Fig 312, 5 days after the application of wire traction with 7 Kg., as on the right side. A lengthening of 0.5 cm. was produced. Indistinct callus cloud arising from the distal fragment but much less than on the right side (Fig 308) Treated *elsewhere.*

Fig 314 Same as Fig 313 after 6 days, or 28 days after the accident. In contrast to the right side (Fig 309) callus formation did not increase. Lengthening of 0.5 cm. Since this was not recognized the weights were increased from 7 to 9 Kg

Fig. 315 Same as Fig 314 after 7 days, or 35 days after the accident. The lateral displacement has diminished. A lengthening of 1.5 cm. developed. In contrast to the right side (Fig 310) callus formation has not increased.

Fig 316 Same as Fig 315 after 28 days, and 25 days after medullary nailing or 63 days after the accident Distinct periosteal callus has formed.

For closed fractures of the lower leg, positioned as in Fig II/2374 a traction of 3 Kg is, as a rule sufficient. In infected fractures the weight must occasionally be reduced to 2 Kg or even 1 Kg I have always used these weight proportions, as evident from my treatise "Über eine Einheitsbehandlung der Unterschenkelbrüche", M m W No 3 1918 In old fractures of the lower leg, traction in some cases may have to be increased to 10–15 Kg for a few days (Figs 922–931)

For fractures of the humerus skeletal traction is necessary only in exceptional cases (see page I/456) No more than 1 5–2 Kg must ever be used, and 1 Kg is frequently sufficient

In forearm fractures, skeletal traction will as a rule, only cause damage

In order to be able to count the weights at a glance we never attach more than 5 Kg to one rod If less than 10 Kg are used, e g , 8 Kg one rod will hold 5 Kg

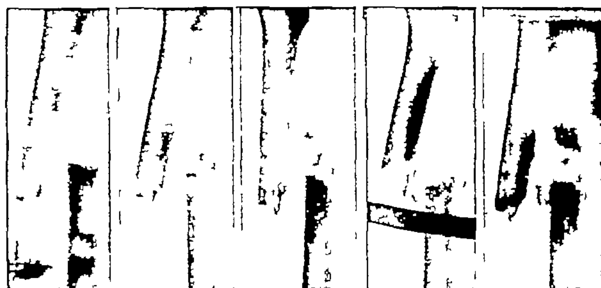


Fig. 307 July 31 1942 — Fig 308 August 4, 1942 — Fig 309 August 10 1942 — Fig 310 August 17 1942 — Fig. 311 September 15 1942

Fig 307 Fracture of the right femur above the middle in plaster cast, 17 days after the accident in a 19-year-old young man, height 182 cm. weight 72 Kg both of whose thighs were run over by an automobile on July 14 1942 At the same time he suffered a fracture of the left femur (Fig. 312) and a dislocation of the left hip with paralysis of the sciatic nerve The distal fragment shows typical adduction and medial displacement by 1½ times the width of the shaft. Shortening, 4 cm.

Fig. 308 Same as Fig 307 5 days after the application of wire traction with 7 Kg. Angulation and lateral displacement slightly increased. Shortening, 3 cm. Distinct callus clouds. Treated elsewhere

Fig. 309 Same as Fig 308 after 6 days, 28 days after the accident. Angulation corrected, shortening unchanged, 3 cm. Traction weight increased from 7 to 12 Kg.

Fig. 310 Same as Fig 309 after 7 days, or 35 days after the accident. In spite of the heavy traction the shortening remains unchanged. There is again a varus angulation. Marked increase of callus formation.

Fig. 311 Same as Fig 310 after 28 days, or 63 days after the accident. In spite of continuous traction of 12 Kg. the shortening of 3 cm remained unchanged. Strikingly marked callus formation arising only from the proximal end of the distal fragment, whereas the proximal fragment shows no trace of callus formation as in Figs 299 and 300 Varus angulation of 10° Fracture clinically firm. Later osteotomy and medullary nailing

Experience teaches us that in fresh closed fractures of the femur in patients with average muscular development the weight required for traction is as a rule, one seventh of the body weight if the leg is positioned as pictured in Figs II/1604–1606 on a Braun leg frame with the foot of the bed elevated Thus in a patient weighing 70 Kg the traction should amount to 10 Kg If traction is applied above the knee joint, no more than one-eighth of the body weight must be applied thus only 9 Kg in a patient weighing 70 Kg under the afore mentioned conditions In old patients with weak muscles and in compound fractures at the most one tenth of the body weight should be used (Figs II/2159–2164) As soon as an infection occurs at the site of the fracture even this amount of traction is too great and should be reduced to 6 or even 3 Kg in a patient weighing 70 Kg (Figs. 322–351) In old closed fractures of the femur with marked shortening a traction of 15–20 Kg is sometimes necessary, but always for a few days only (Figs II/1866–1869)

302) When the traction was removed 4 months after the accident, angulation and shortening had recurred (Fig 303) Although the fragments were now in a position favorable to callus formation similar to Figs 291 292 none developed Figure 304 shows that even 7 months later callus formation was very scant

In this case the excess of 2 Kg was sufficient to distract the fragments by 10 mm From the case history and the numerous X ray pictures it is evident that all efforts were directed merely against the lateral displacement shown in the lateral X ray picture (Fig 302) Various inadequate measures were taken The separation of the fragments was not noted Many do not realize that a lateral displacement by the full thickness of the shaft is entirely irrelevant for future function if no angulation and only a slight shortening exists (Figs. I/196–215), but that any lengthening causes severe damage Of particular interest is Fig 303 which shows that, in spite of a shortening which had existed for 4 weeks, similar to Fig 291, no callus formed because the capacity of the tissues to form callus had been lost by 4 months of overstretching A repeated application of continuous traction proved unsuccessful for the same reason (Fig 304) That local disturbances at the fracture site only, and not a general condition, prevented callus formation, is evident from the fact that prompt union occurred after the fragments were freshened and the medullary nail used Some surgeons who do not believe in the detrimental influence of excessive traction have objected that callus formation failed to occur because the excessive traction was applied as early as the second day and not on the 10–12th day as in those midgets in which Bier performed a bone lengthening The important difference, however, lies in the fact that Bier's operation was performed on young people with maintained epiphyses.

Case 2 A 19-year-old male patient weighing 72 Kg. and with a height of 182 cm. was struck by an automobile on July 14 1942. He suffered transverse fractures of both femora and a posterior superior dislocation of the left hip with paralysis of the left sciatic nerve He was given a hip spica including both legs without previous reduction of the fractures or of the dislocation which had been overlooked (Figs 307 and 312) and in this cast he was transported for 800 Km On July 31 i e after 17 days the plaster cast was removed and a wire extension was applied to each tibial tuberosity with 7 Kg each. The X rays 5 days later showed that a shortening of 3 cm. persisted on the right side, whereas on the left side a lengthening of 0.5 cm. had been produced. On the right side one can see distinct cloudy callus, on the left side only slight evidence of callus (Figs. 308 and 313) After another 6 days the callus formation was marked on the right side on the left however it had not increased (Figs. 309 and 314) The traction was then increased on the right side by 5 Kg and on the left side by 2 Kg Seven days later the shortening remained the same on the right side with callus markedly increased (Fig 310) On the left side a separation of 1.5 cm. developed Although the lateral displacement had diminished, there was only a slight trace of callus formation (Fig 315)

This case demonstrates that excessive traction delays callus formation. Both of the patient s femora were broken and displaced in approximately the same way at about the middle of the shaft. Both were treated with a plaster cast for 17 days and then received wire extension with 7 Kg to the tibial tuberosity Since an unrecognized dislocation existed in the left hip the distance from the pelvis to the knee was 5 cm shorter than on the right side and the muscles therefore relaxed The same trac

and the other 3 Kg ,—not 4 Kg on each A weight of 6 Kg will not be placed on a single rod but distributed between 2, one carrying 5 Kg and the other 1 Kg (Fig II/1606)

For any given patient weights of the same size should be used and not weights of various sizes such as 1 Kg , 2 Kg , 2.5 Kg or 3 Kg etc., because it consumes too much time to compute the weight, and thus this is often omitted. For convenience in changing the weights, these are not fastened to strings but are slid on rods since untying them from strings would take too much time If a change of weights is merely ordered and not carried out on the spot, one will too frequently find on the next round, that the order has not been carried out.

That the size of the weights has not received the deserved attention is evident from Kirschner's following description

"It is important that the physician be able to see with one single glance the full amount of the weights. The commonly used sand bags do not fulfill this requirement. Often the sand bags leak and their weight therefore is unknown Still less ornamental are sand-filled buckets, old preserve cans or gasoline cans frequently used by ambulant patients as ash trays and waste paper baskets. In general one may find all kinds of objects used as weights for traction from tools which ought to be used for some more fitting purpose to valuable parts of fracture tables bases of dismantled floor lamps and even rusty iron pieces of junk. If an inquiry is made as to the total weight of such metal collections the experts involved immediately start figuring studiously and obtain quite a variety of results.

Weights for continuous traction should be used with careful dosage, like a poison ous medication Or comparison may be made to the use of table salt. If food has not been sufficiently seasoned, more salt can be added, a meal once over salted is irreparably spoiled

Not only the distribution of the weights but even the wire extension itself, is often not applied adequately as is evident from the remarks of Kirschner

'It must unfortunately be said that the right application and adjustment of a wire extension is rather rare and it is hardly an exaggeration to state that among 100 wire extensions less than 10 are applied in such a manner as to ensure best results.

"The deplorable lack of expert skill in this most important procedure in the treatment of fractures during war or peace is predominantly due to the fact that many surgeons have neith r the inclination nor the interest for mechanical problems and because only few physicians can or want to delve deeply into the mechanical laws of wire extension and their effects. Furthermore, many physicians leave the subsequent supervision of cases to attendants and nurses shifting any responsibility for mistakes quite naturally upon the shoulders of their help

After describing adjustable splints Kirschner continues But even the possession of the best splints is valueless if they are adjusted badly and used wrongly This is frequently the case, in fact, almost regularly "

What damage may be caused by excessive continuous traction is best illustrated by the following case histories

Case 1 A 21 year-old man of medium build 165 cm. in height and weighing 62 Kg suffered a closed fracture of the left femur in an automobile accident A wire extension was applied to the femur with a weight of 10 Kg X ray pictures after 7 weeks showed no trace of callus (Figs 301

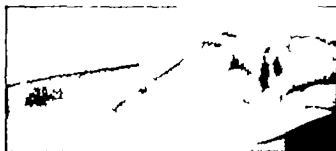


Fig 317
November 1 1941
Fig 317 Fracture of the left femur 12 cm proximal from the knee with typical angulation and shortening in a 38-year-old miller height 163 cm, weight 65 Kg, who was run over by a truck



Fig 318
November 22 1941
Fig 318 Same as Fig 317 after 3 weeks. Wire traction with 12 Kg was applied *elsewhere* The fracture has been pulled up to the angle of the leg frame and a sand bag is lying beneath the fracture. The knee joint is raised considerably from the horizontal part of the frame this is a sign that the pulley for the traction cord is placed too *high* as in Fig II/1998 b.



Fig 319
December 10 1941
Fig 319 Same as Fig 317 after 6 weeks. The sand-bag has been *placed more distally* The angulation remains the same because the traction is still applied too steeply

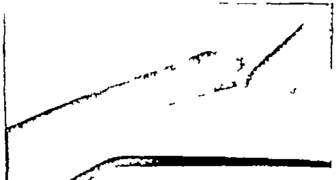


Fig. 320
December 29 1941
Fig 320 Same as Fig 317 after 8 weeks. The *excessive traction has pulled the fracture far beyond the angle of the leg frame.* The angulation has increased because the traction pulley is still too high.



Fig 321
January 10 1942
Fig 321 Same as Fig 317 after 10 weeks In spite of excessive traction callus has formed The fracture healed with a recurvation of 25° Such angulations disappear immediately if the pulley for the traction is lowered in the beginning of the treatment, as in Figs. 673 F II/1998 a or if the fracture site is raised, as in Fig II/2009

tion of 7 Kg which was not sufficient to eliminate the shortening on the right side, produced a lengthening of 0 5 cm on the left In order to correct the shortening, weight was increased by 5 Kg on the right side Also on the left side 2 Kg were added, probably because the existence of a slight separation had not been recognized. On the 34th day after the injury it was evident that even the weight of 12 Kg was insufficient to reduce the shortening on the right side (Fig 307), because in spite of the lateral displacement by double the thickness of the shaft, callus had formed and had become so strong that the fracture was clinically firm, in the same period of time as that in Figs 291 292 On the left side, however callus formation was almost non existent because of the distraction

One might infer that on the left side the paralysis of the sciatic nerve might have interfered with callus formation That this is not the case is evident in Fig 316 showing distinct callus formation 25 days after freshening and medullary nailing

Subsequently the left hip was reduced by open procedure and the right femur was treated with a medullary nail for the elimination of shortening and angulation Both femora united in ideal position The left hip became stiff

Figures 307–311 are fundamentally important because they show that, in spite of lateral displacement by double the thickness of the shaft which must have been accompanied by marked interposition of soft tissues extensive callus will form rapidly if a shortening exists and if the fragments are well immobilized, as they were in this case for 17 days by a double hip spica. This proves that even a massive interposition of muscles does not interfere with callus formation, much less cause pseudarthrosis With this type of displacement callus usually forms from the proximal end of the distal fragment whereas the proximal fragment forms no callus at all (Figs 299 300)

Figures 312–316 show that even a lengthening of 0 5 cm delays callus formation, especially if the fragments are also displaced laterally Callus formation stopped here although it had already started during the 17 days of immobilization in a plaster cast as shown in Fig 313 The contention that too early excessive traction delays callus formation as in Figs 301–304 is not supported by this case because, following Bier it was not applied until the 17th day

Most interesting is the influence of excessive traction in long spiral fractures of the tibia Even though the fragments are facing each other for a length of 6–10 cm. with slight lateral displacement callus formation is markedly delayed where a lengthening had existed (Figs II/2390 2391) and even pseudarthrosis may develop

Case 3 A 38-year-old man weighing 65 Kg and 162 cm. in height suffered a transverse fracture of the left femur with typical angulation and shortening (Fig 317) He was placed on a Braun leg frame and wire traction was applied to the tibial tuberosity with 12 Kg The excessive traction caused a lengthening of the leg but because of inadequate position and faulty direction of the traction the angulation had not been eliminated (Figs 318–321)

From over 20 X ray pictures accompanying the case record it is evident that repeated attempts were made to correct the angulation They did not succeed because the direction of the traction was too high as shown in Fig II/1998b Because



Fig 327 Fig 328 Fig. 329 Fig 330

June 4 1942 May 5 1943



Figs. 331-333
May 5 1943

Figs. 331-333 Same as Figs 322-330 3 years after injury Shortening 14 cm. Toes stiffened in flexion foot in equinus position and knee stiffened at an angle of 160° Dorsum of foot swollen lower leg markedly wasted. If such comminuted fractures are not distracted, they usually unite and can bear weight in 6-10 weeks. The inflammation is milder and the muscles and joints are not damaged. Occasionally even the knee joint regains normal motion No paralysis of the sciatic nerve develops.



Fig. 322 June 18 1940 | Fig 323 July 3 1940 | Fig. 324 August 13 1940 | Fig. 325 Fig. 326 December 9 1941

Fig 322 Gunshot fracture of the right femur with a comminuted area of 13 cm., in a 27 year-old man from rifle shot on June 10, 1940 After 2 days, wire traction with 6 Kg was applied. Treated elsewhere Motion of toes free

Fig. 323 Same as Fig 322 after 15 days. Traction was increased to 10-15 Kg. This caused a separation of the fragments, inflammation and abscess formation as in Figs. 334-341

Fig. 324 Same as Fig 322 after 8 weeks. Several splinters have sequestrated. The fragments are widely separated. The toes cannot be moved.

Figs. 325 326 Same as Fig 322 after 1½ years. Continuous traction was removed after 6 weeks, then hip spica for 8 months. Shortening, 10 cm. Varus and antecurvation of 20° each. A thin eburnated bridge of bone connects the fragments.

Figs. 327 328. Same as Figs. 325 326, after 6 months. Slipped 4 months earlier and broke the thin inelastic bridge of bone. Again hip spica for 4 months and brace for 6 months.

Figs. 329 330 Same as Fig 322 after 3 years. Again bony union. Shortening 14 cm. Varus angulation 30° antecurvation 25° The bridge between the 2 main fragments is stronger than on December 9 1941

a large fragment maintained contact between the posterior edge of the proximal fragment and the anterior edge of the distal fragment, because a large fragment lay in front of the fracture and because the fracture had occurred in a place where delayed callus formation and pseudarthrosis are very rare even under detrimental influences callus formed rapidly in spite of the excessive traction but healing occurred in mal position (Figs. 693 694)

Case 4 A 27 year-old strong man 175 cm. tall, 71 Kg in weight suffered a comminuted gunshot fracture of the right femur on June 18 1940 (Fig 322) The shortening was 3 cm. After 2 days wire extension with 6 Kg was applied to the tibial tuberosity After 5 days traction was increased to 10 Kg., and after another 7 days, to 15 Kg This was followed by inflammation with high temperature and abscess formation. The fragments (Fig 323) had separated In the third

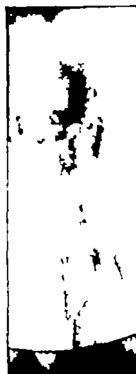
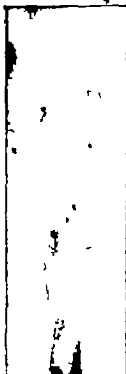
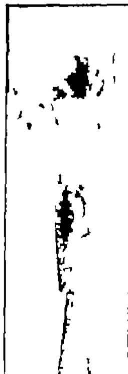





Fig. 338 January 13 1943 · Fig 339 March 30 1943 · Fig. 340 · Fig 341 June 14 1943




Fig 342 · Fig 343

June 22 1943

Fig 342 343 Same as Figs 334–341 13 months after injury and 1 month after removal of the last hip spica The left leg is 3 cm. longer than the well right leg. It is swollen and shows a bluish discoloration Toes and ankle joint one half free. Knee 180–175 against 180–40° on the right side Such comminuted fractures are usually firm and fit to bear weight in 6–10 weeks if they are not subjected to excessive traction. The circulation remains normal and the motion is generally only slightly impaired General condition good. He has regained his previous weight of 66 Kg

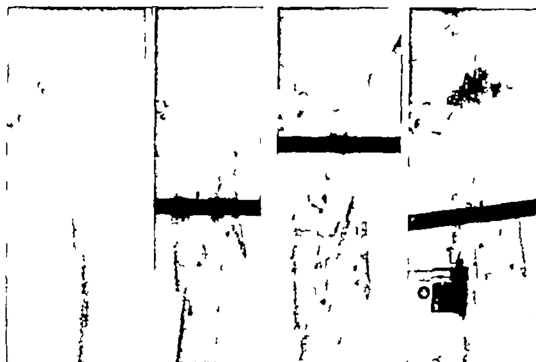


Fig 334 June 10 1942 | Fig 335 June 18 1942 | Fig 336 July 8 1942 | Fig. 337 October 27 1942

Fig. 334 Gunshot fracture of the femur in a 24-year-old man height 165 cm., weight 53 Kg Comminuted area 15 cm Distance from the tip of the minor trochanter to the tip of the most distal fragment, 16.5 cm. X ray picture taken in the cast 30 days after injury Shortening after removal of the cast, 1 cm.

Fig 335 Same, 8 days after the application of wire traction with 6 Kg. The fragments are widely separated because the weight of 6 Kg was too much in this case. At the most, 5 Kg should have been used. Distance from the tip of the minor trochanter to the lower fragment 19.5 cm., i.e. a *lengthening* of 2 cm. beyond the normal. On June 13 high fever as in Fig 323 Treated *elsewhere*.

Fig 336 Same as Fig 335 after 20 days. Although the traction of 6 Kg. was not increased, the fragments continued to separate because the muscles had been further weakened by the inflammation and abscess formation. Distance from the tip of the minor trochanter to the lowermost fragment 24.5 cm There is thus a *lengthening* of 7 cm

Fig. 337 Same as Fig 334 after 4½ months, and 3 weeks after reduction of the weight from 6 to 5 Kg *Lengthening* is now 6 cm. as compared with 7 cm. on July 8 Beginning callus formation.

Fig 338 Same as Figs 334 335 after 7 months, and 2 months after the application of hip spica. *Lengthening* is 3 5 cm Callus formation increased Fracture still very loose, therefore new hip spica applied.

Fig. 339 Same as Figs 334 and 335 after 9 months. *Lengthening* 3.5 cm. Callus formation further increased Fracture still somewhat springy therefore new hip spica.

Figs 340, 341 Same as Figs 334 and 335 after 12 months, and 14 days after removal of the last cast. *Lengthening* 3 cm Bony union In the lateral view a gap is still visible. The bridges of callus are eburnated. Good alignment. Such fractures are as a rule, firm and fit for weight-bearing in 6–10 weeks, if excessive traction is avoided

week he was unable to dorsi-flex the toes or the foot and a few days later even plantar flexion was lost. After 4 weeks the weight was reduced to 8 Kg and it was not removed until 6 months later when a hip spica was applied for 8 months (Figs 329 330) After 20 months he slipped and re fractured the femur (Figs 327 328) Again a plaster cast was used for 4 months and a brace for 6 months.







Fig 348 January 4 1944 — Fig 349 Fig 350 March 12 1945 — Fig 351 January 4 1944

Fig. 348. Same as Figs 344–347 19 months after injury The treatment consisted of wire traction for 7 months, hip spica for 5 months, then orthopaedic brace The broken leg is 3 cm. shorter and much weaker than the left one. Motion of the knee joint 170–150°

Figs. 349 350 Same as Figs. 344–347 14 months after freshening of the fragments, medullary nailing and implantation of a 15 cm. massive tibial graft which was fastened with 3 circumferential wire sutures. Bony union of the graft. Patient can walk without a cane

Fig. 351 Same as Figs. 348–350 The right foot has become shorter and narrower than the left. If continuous traction with 3–4 Kg. had been used in this patient, the fracture would probably have united and become fit to bear weight within 10–12 weeks and the knee joint would show good motion

In contrast to closed fractures excessive traction in open fractures will cause not only a separation of the fragments but as a rule also an increased inflammation and with it separation of numerous sequestra The result is then a shortened bone with a thin bridge of callus which is eburnated and inelastic because it contains no cancellous bone and therefore refractures easily One can say that the final shortening and deformity is as a rule in direct proportion to the excess of traction used Such cases can be seen frequently whereas pseudarthrosis produced in the same way is comparatively rare, as shown in Figs 344–351 735–783 and 940–971

Case 5 A 24-year-old male patient, weighing 53 Kg and 165 cm. tall, suffered a comminuted gunshot fracture of the left femur on May 11 1942 He received a plaster spica for a long transportation. After removal of the spica thirty days later a shortening of one cm. existed. Wire traction was applied to the tibial tuberosity with a weight of 6 Kg Three days later inflammation with pain and high temperature necessitated incision. Although the weight was not increased a marked lengthening of the leg resulted. Five months later a plaster cast was applied which was removed after seven months.

In this case, a weight of only 6 Kg not merely corrected the shortening but even produced after eight days, a lengthening of 2 cm (Fig 335) The fragments

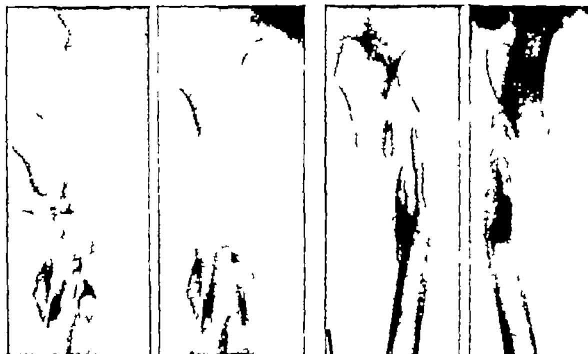


Fig 344 August 28, 1942 — Fig 345 December 21 1942 — Fig 346 — Fig. 347 January 4, 1944

Fig 344. Gunshot fracture of the right femur in the upper third in a 21 year-old man, height 165 cm., weight 48 Kg on June 12, 1942 Condition as seen 1 day after application of wire traction with 10 Kg weight. The main fragments have separated There is a lengthening of 3 cm. Treated *elsewhere*.

Fig. 345 Same as Fig 344 after 4 months still under continuous traction of 8 Kg. The main fragments separated still further There is a *lengthening* of 7 cm

Figs. 346 347 Same as Fig 344 after 16 months. There is a shortening of 3 cm The fragments did not unite (pseudarthrosis) The 2 prongs of the distal fragments are eburnated.

Because this was a compound fracture, the excessive traction not only caused separation of the fragments but also led to a flare up of the inflammation with formation of abscesses and sequestration of numerous small bone splinters, and to paralysis of the sciatic nerve (Fig 324) Therefore a large gap remained between the main fragments when the traction was diminished. The proximal fragment shows a longitudinal fracture line which had become wider it also shows marked periosteal appositions Traction for 6 months and a hip spica for 8 months led to bony union after a total of 14 months with shortening of 10 cm and considerable angulation A year and a half after the injury the bridge of bone between the main fragments was still thin, eburnated and consequently inelastic (Figs 325 326) Therefore it broke when the patient slipped in the 20th month (Figs. 327 328) Further immobilization for another 12 months resulted again in bony union, with a shortening of 14 cm and increased angulatory deformity (Figs 329, 330) The bridge of callus became stronger because the shortening had become greater The muscles are wasted and the joints stiff (Figs. 331–333) The bone outside the fracture area is markedly decalcified The sciatic paralysis receded during the 4th year

This unfortunate result of three years of treatment and all the complications which brought this about must be ascribed chiefly to excessive continuous traction



Fig 356

June 15 1944



Fig 357

June 15 1944

Figs. 356, 357 Same as Fig 355 after 16 months. The left foot is narrower and shorter than the right shows bluish discoloration and is very painful Thus a dystrophic condition of all tissues of the entire foot developed, not only a decalcification. The toes are in claw position.

almost stiff (Fig 342) Such a lengthening of 3 cm has a much more unfavorable effect than a shortening because the lengthened leg carries more burden and because the lengthening cannot be compensated for by tilting the pelvis nor by a slight flexion of the knee joint of the longer leg since this joint is stiff

If in this case the first plaster cast had been left on or replaced immediately by a new one, or if traction had not been excessive, a flare up of the inflammation would most likely not have occurred certainly not a separation of the fragments The fracture would probably have united in 6 or, at the latest, in 10 weeks and the severe circulatory disturbances, the decalcification, the wasting of the muscles, and the stiffness of the joints would not have developed

Case 6 A 21 year-old male patient, height 165 cm., weight 48 Kg suffered a comminuted gunshot fracture of the right femur After three days, wire traction with 10 Kg was applied to the tibial tuberosity *elsewhere* This was reduced to 8 Kg after 3 weeks and was continued for 8 months Thereafter plaster spica for another 4 months. Later a brace was worn

In this infected comminuted fracture the weight used constituted one fifth and later one sixth of the body weight and not one tenth, in other words twice the permissible maximum weight consequently, a lengthening of 3 cm developed at first, later one of 7 cm After removal of the continuous traction the main fragments approximated resulting in a shortening of 3 cm Since the fragments in contrast to Case 5 (Figs 334–341) were without contact for eight months, a pseudarthrosis developed (Figs. 348–349) The dystrophy of the entire leg was evident not only from the marked weakness of the muscles and marked restriction of joint movements, but also from the fact that the entire foot became narrower and shorter (Fig 351)



Fig. 352 August 22, 1942 Fig 353 Fig. 354 November 18, 1942 Fig 355 February 22 1943

Fig 352. Transverse fracture of the left tibia and double transverse fracture of the fibula, in a 32 year-old man who was run over Treated *elsewhere* with wire traction of 10–15 Kg. for 10 weeks.

Figs. 353 354 Same as Fig 352 after 3 months. The fragments of the tibia are separated 15 mm. *Marked decalcification especially at the epiphyseal line. No trace of callus formation.* Toes almost immobile in claw position and both ankle and subastragalar joint show only a few degrees of motion Marked muscle atrophy left femur 39 cm against 46 cm on the right femur left lower leg 29 cm. against 35 cm. on the right leg

Fig 355 Same as Fig 354 X-ray picture of the ankle joint after 6 months. Extraordinarily marked, mottled decalcification of all tarsal bones and of the epiphyseal line of the tibia.

show considerable separation although the weight amounted to only 6 Kg it was too much for this man who was greatly debilitated from war service Therefore, inflammation abscess formation and a further weakening of the muscles ensued Although the weight was not increased a lengthening of the leg by 7 cm developed after another 3 weeks (Fig 336) The fragments are widely separated Although new X rays were taken in both planes every two weeks, no one noticed the distraction The reports about the pictures refer only to the satisfactory alignment. It was not until four months later that the weight was reduced to 5 Kg whereupon the shortening receded from 7 to 6 cm (Fig 337) During the 7 months immobilization in a plaster cast the separation receded to 3 cm (Figs. 338–341) If long fragments are present which do not sequestrate a lengthening once produced frequently cannot be eliminated again If the weight is then reduced too much angulations usually occur

In the above case bony union with 3 cm lengthening occurred after one year in spite of the separation of the fragments, because the long distal fragments were separated like the prongs of a fork and the proximal fragment lay between them The alignment is good As seen in the lateral view the bridges of callus are still thin (Fig 341) The leg is not only lengthened but also very thick and bluish the toe and ankle joints were limited to one half their normal range and the knee was



Fig 362 Fig 363 Fig 364 Fig 365

May 3 1943 January 11 1944

Figs. 362, 363 Same as Figs 358 359 after 9 months. Both main fragments of the tibia are united anteriorly by a narrow eburnated bridge of bone behind it is a large cavity In the lateral view posterior angulation of 30° A sequestrum is located between the fragments of the fibula.

Figs. 364 365 Same as Figs 358 359 after 17 months, and 4 weeks after removal of the anterior bone bridge and shortening of the fibula to permit approximation of the tibial fragments. Good alignment in both views. Fracture united in January, 1945 i e., 2½ years after injury

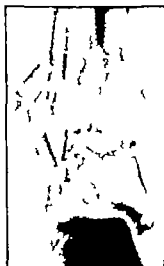
After freshening the fragments and medullary nailing, bony union occurred, proving that no systemic deficiency was present.

In fractures of the lower leg pseudarthrosis is a much more common sequela of excessive traction than in fractures of the femur (Figs. 922–931, 940 943, 944–951, 952–959, 960–971)

Disturbance of Callus Formation through Single and Double Skeletal Transfixion Casts

Some fractures of the lower leg and of the forearm especially isolated fractures of the radial shaft, show a marked tendency to angulation and shortening This can be avoided by drilling one or two wires through the fragments the metacarpal bones or the os calcis and incorporating them into a plaster cast (Figs 395–404 827–837 E, I/936–945 II/2434–2449) In using this method one must watch closely to see that the fragments are not separated before the cast is applied, because with this method the fragments are retained in an 'iron grip' and cannot approximate If this procedure, which if properly used can give excellent results, is applied to a gaping fracture as in Figs 358 359 serious damage is done It is perfect nonsense to use double transfixion or continuous traction in isolated fractures of the tibia after extensive removal of fragments or in pseudarthrosis, as shown in Figs 972–975

Hip spica transfixion has been recommended for fractures of the femoral shaft The damage from this is generally not so serious, because as a rule only one wire is used through the tibial tuberosity and because the pelvis can slide down into the plaster cast thus the fragments can approximate



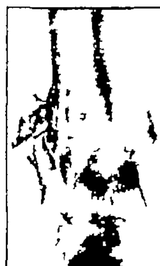



Fig. 358 Fig. 359 Fig. 360 Fig. 361

August 11 1942 November 2 1942

Figs. 358, 359 Comminuted fracture of the right lower leg 5 weeks after injury under continuous traction with 6 Kg. The main fragments are separated 2 cm The ankle joint is widened. In a 30-year-old man, injured by an explosive bullet on July 8, 1942 A double wire transfixion cast was applied in this position (Figs. II/2441–2443) and left for 6 weeks. Then the cast was removed because of suppuration around the wires. Treated *elsewhere*.

Figs. 360 361 Same as Figs. 358, 359 after 3 months. The fragments approximated after removal of the transfixion cast Marked decalcification of the ankle joint.

In fractures of the femur excessive traction most often leads paradoxically to considerable shortening and angulation, as in Figs. 322–333 Lengthening as in Figs 334–343 and pseudarthroses (Figs. 344–351 and 232–243, 301–304, 735–783) are less common The greatest impression was made upon me by a patient with a gunshot fracture of both femur bones In a plaster spica he did well for 3 weeks. Then excessive traction was applied on both sides. This was followed by severe infection necessitating amputation of the left leg whereas the right leg was saved with a pseudarthrosis and paralysis of the sciatic nerve

Refractures are not uncommon. They are frequently ascribed to nutritional deficiencies due to war to vitamin deficiencies or to gland deficiencies, and the patients are given corresponding medication If the X ray pictures of such cases are studied one will usually find that excessive traction had been used and that an ineffectual eburnated callus had formed (Figs. 327 328)

Case 7 A 32 year-old male patient was run over and suffered a transverse fracture of the tibia in the lower third and a double fracture of the fibula (Fig 352) He was treated with wire traction through the heel for 10 weeks using 10 Kg at first later 15 Kg A plaster cast was then applied for 6 months. End result—pseudarthrosis.

Because excessive traction was used the fragments of the tibia were separated by 15 *mm* and callus did not form also marked decalcification of the entire foot and of the epiphyseal line of the tibia developed (Figs 353–355) The toes were fixed in claw position The ankle joint and the sub-astragalar joint were stiff and the muscles wasted The foot was blue cold and moist.

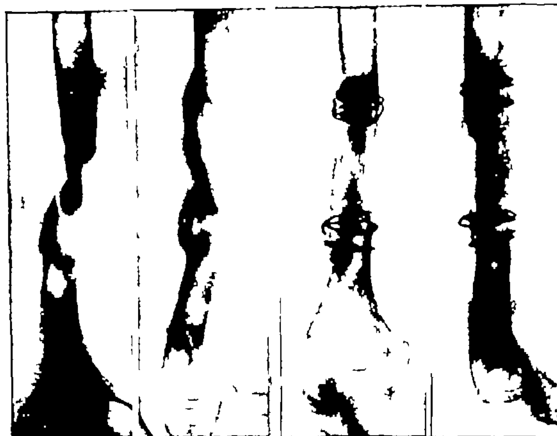


Fig 369 Fig 370 Fig 371 Fig 372

October 10 1944 January 9 1945

Figs. 369 370 Same as Fig 366, after 14 months. The thin eburnated callus broke in the cast during exercises with the horizontal pulley

Figs. 371 372. Same as Fig 366 after 17 months, and 3 months after implantation of a massive tibial graft which united firmly

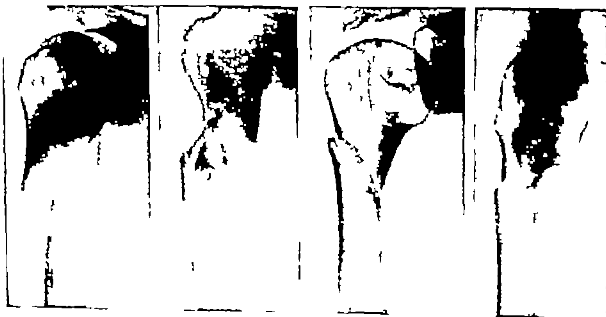


Fig. 373 Fig. 374 Fig 375 Fig. 376

April 4 1944 April 4 1944



Fig 366 August 4 1943 — Fig. 367 October 13 1943 — Fig 368 March 6 1944

Fig 366 Gunshot fracture of the right humerus with marked comminution in a 28-year-old man from rifle-shot on July 25 1943 Small wounds which healed in 14 days. Distance of the main fragments, 24 mm. *Elsewhere* a shoulder spica was applied under traction.

Fig 367 Same as Fig 366 after 10 weeks. The main fragments are separated 36 mm. Slight callus formation therefore another shoulder spica was applied

Fig. 368 Same as Fig 366, after 7 months. Distance of main fragments 47 mm. therefore another shoulder spica was applied *elsewhere*.

Figs. 373 374 A 6-weeks-old leverage fracture of the right humerus with lateral displacement by half the shaft's thickness and shortening of 2 cm., in a 76-year-old farmer who fell on his hand. Treated with a Desault bandage. Good callus formation after 21 days. Fracture clinically almost firm therefore, the bandage was removed. Active exercises started on horizontal pulley After 6 weeks, the motion of the fingers, hand elbow and rotation of the forearm are actively free. *Shoulder can be moved with the help of* the other arm through almost the full range.

Figs. 375 376 A 13-weeks-old high oblique fracture of the right humerus with lengthening of 3 mm., in a 36-year-old housewife from a fall on the street. Treated *elsewhere* for 12 weeks with a shoulder spica which was applied under strong traction The fragments are separated by 3 mm The fracture surfaces are operculated. Finger motion free Wrist joint and forearm rotation one-half restricted. Elbow 75–130° The arm can be raised laterally only 80° at the shoulder Muscles weak

In a chest-shoulder arm spica a wire through the olecranon is unnecessary because the cast alone prevents the approximation of the fragments.

Delay of Callus Formation by the Thoraco Brachial Spica

The majority of the gunshot fractures of the humerus I reported in 1918[*] united firmly in 4–6 weeks. They were usually treated with an abduction splint, with or

[*] Böhler Spezialabteilungen für Knochenschussbrüche und Gelenkschüsse nahe an der Front. Zeitsch f orthop Chirurgie, 38 1918

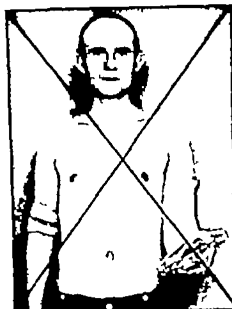


Fig. 380



Fig 381

Fig 380 Same as Fig 379 seen from the front The hand is supinated. If it heals in this position it will be good only for begging

Fig 381 Perforating gunshot injury of the wrist joint with negligible infection. Was placed on an abduction splint made of Cramer wire ladders which was poorly fastened to the chest. Wire traction through 2nd to 4th metacarpal and through the olecranon. Screw traction is applied to both traction bows. With this arrangement the patient was transported more than 1000 Km Because the wrist joint was distracted and therefore painful, the fingers could not be moved swelled and became stiff A simple dorsal plaster splint which leaves the fingers entirely free, as in Figs 429–432 E, I/1069–1072, is the best treatment for this type of injury

tion is marked restriction of motion of the entire arm A new feature of this treatment is a stubborn abduction contracture of the shoulder which was unknown before

The comparison of two fractures of the upper third of the humerus which I saw on the same day is particularly instructive as to the damage arising from a chest shoulder spica which had been applied under excessive traction One was a 76-year old farmer who broke his humerus by a fall He was treated for three weeks with a Desault bandage in which he moved the fingers and rotated the forearm Upon removal of the bandage the X ray pictures showed a shortening of 2 cm , antecurvation of 15° and good callus formation The fracture was clinically so firm that it was possible to raise the arm without pain I gave him a sling and started him on active exercises on a horizontal pulley, as described on page I/429 Three weeks later there was normal active motion of the fingers, wrist, forearm and elbow, and with the help of the other hand he was able to move the shoulder through almost the full range There was no swelling anywhere The X ray pictures showed that the angulation had disappeared and that the callus had increased (Figs 373 and 374)

The other patient in contrast was a 36-year-old woman, otherwise healthy, who showed marked restriction of motion swelling and pain in her arm She had suffered a fractured humerus 13 weeks before (Figs 375 376) The arm had been



Fig. 377

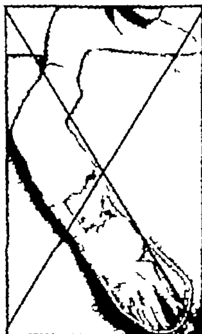


Fig. 378



Fig. 379

Fig 377 Gunshot fracture of the ulna with banjo splint.
Fig. 378. Gunshot fracture of the radius with banjo splint.
Fig. 379 Gunshot injury of the wrist joint. The forearm is supinated. In all 3 cases, the wrist joint is slightly flexed and the metacarpo-phalangeal joints are hyper-extended. The elbow is not sufficiently flexed and the upper edge of the cast presses upon the radial nerve. With such an arrangement the fingers are bound to stiffen

without adhesive plaster traction Fingers wrist and forearm were exercised actively from the first day in every case and in those fractures which were not too close to the elbow this joint also was exercised (Figs. 349 350 E I/589, 590 and I 741–746) In this way the fragments were never pulled apart but rather subjected to stimulating intermittent pressure by vigorous exercises During the recent war I found that in many places humerus fractures took 6 to 12 months for union and that pseudarthroses and refractures occurred frequently The X ray pictures often showed a wide separation of the fragments as in Figs 366 367 Upon investigation I found that many had been treated with continuous wire traction through the olecranon for many weeks or even months with 5–6 Kg or even 10 Kg and that a chest shoulder arm spica had then been applied because the fracture did not unite under traction (Figs 289 290) In most cases a spica was applied under strong manipulative traction without previous continuous traction One surgeon used 7 Kg for this procedure Contrary to treatment on an abduction splint with or without adhesive traction the fragments once separated cannot approximate in a plaster cast because they are immovably fixed between the chest and the forearm flexed at the right angle (Fig I 734 a–d) If the fragments are kept separated for several weeks as in Figs 366 367 approximation is very difficult and a thin eburnated callus develops (Figs 368 369) with frequent refractures (Fig 369) as in fractures of the femur (Figs. 325–330) A sequela of the unduly prolonged immobiliza

At the present time so many effective methods are at the disposal of traumatic surgery that in the majority of fractures and other injuries, complete or almost complete restoration can be obtained as proven by Figs 114–133 E, 708–721 E, I/125–192, I/297–323 and innumerable others Of course, parts of organs or limbs which have been destroyed or removed by an accident cannot be replaced

Methods at our disposal nowadays are not only effective but, like all effective measures, are dangerous as well if not applied at the right time, in the right way, and at the right place I mention the plaster cast as an example If in fresh fractures with marked displacement it is applied without padding before swelling has developed and if it is not split, it can cause the most serious circulatory disturbances and even gangrene By splitting it immediately this danger can be avoided

Direct skeletal traction is the most effective method for treating the majority of femoral fractures and many leg fractures, if it is applied to the right location and not too much pull is exerted If applied to the wrong place, it may lead to suppuration of joints and to other serious inflammations and more than a few patients have thereby lost a leg or even life Too much traction delays callus formation or prevents it and may even lead to dystrophy of the entire limb

Kirschner s remarks (see page 106) illustrate how rarely the effective, but at the same time dangerous, wire traction is used correctly According to his statement less than 10% of the wire extensions were applied perfectly, because many surgeons have neither a feeling nor a fondness for mechanical problems and since only few physicians are able or want to visualize the physical laws of skeletal traction and its effect. Even the best splints and frames are used, in his opinion, frequently, if not most of the time, wrongly and are adjusted poorly I myself have had approximately the same experience.

At the present time the situation is such that most physicians know that wire extension is a very effective method. From this they deduce that it is sufficient to use skeletal traction in a fracture as quickly as possible, at any place, to pull on it with any weight for any length of time without inquiring where, what and how long

Many do not even know how much weight they use (see page 106) Neither do they know that skeletal traction is suitable only for fractures of the femur for many leg fractures and for os calcis fractures and that for most other fractures it is generally detrimental, e g , in fractures of metatarsals toes humerus, forearm hand and fingers.

For many fractures and for many fracture dislocations, double wire transfixion with a plaster cast is the best method, but only after exact reduction has been obtained and if the fragments are not distracted. Many, however believe that all that is necessary is to insert wires somewhere for any kind of injury and to build a complicated contraption as shown in Fig 381 after which they pay no more attention to the patient apparently being quite unaware that they have exposed him to serious dangers.

At present many are of the opinion that all physicians are capable of treating

reduced elsewhere three times and a chest shoulder spica applied which she wore for 12 weeks The X ray pictures show, especially in the lateral view, that shortening lateral displacement and angulation had been completely eliminated, but that a lengthening of 3 mm existed The fracture was firm, but there was no periosteal callus and the fracture stumps were operculated

These two cases demonstrate like an experiment, that callus formation is greatly delayed even by a very slight lengthening of the bone, whereas with shortening it is rapid even in the aged Still more striking is the difference in motility, strength and circulation It must further be emphasized that the woman was suffering pain, whereas the old man was not

Disturbance of Callus Formation through the Banjo Splint

This method (Figs. 377–389) is very popular and attracts great attention everywhere I have seen only serious disturbances from it. Immobilization is inadequate, therefore the patients have pain and the inflammation does not subside. The wrist drops into slight volar flexion and the metacarpo-phalangeal joints move into slight hyperextension and stiffen in this position Callus formation is defective or absent Because of the unfavorable position, not only the injured fingers but also the others lose their function No after-care of any kind can remobilize such fingers *This method must therefore be completely eliminated because its use will cripple any hand even if it suffered only a comparatively light injury*

Prevention of Damage from Distraction

Since the damages caused by excessive continuous traction by transfixion by the shoulder spica and by the banjo splint are quite serious as shown in Figs 301–389 and many others the question arises whether these methods should not be restricted or completely discarded

For this reason it is important that surgeons finally realize that distraction actually causes damage Further they must learn to recognize it. And finally they must have the necessary knowledge and skill to avoid excessive traction in all its forms and the damages arising from it by a proper choice of method and its application

Not until then can one expect that definitely detrimental methods such as the banjo splint will be eradicated that effective methods will actually be used to obtain a cure and that the senseless administration of glandular preparations of vitamins, calcium sulfa preparations blood injections irradiation massage etc will be omitted since the simplest and only correct method consists in removing one or more kilograms of weight from the continuous traction

It must be emphasized again and again that following every fracture an absorption of one or more millimeters of bone takes place at the fracture stumps and that the most important task is to **achieve a corresponding shortening** *in order to prevent a separation of the fragments with all its deleterious effects*

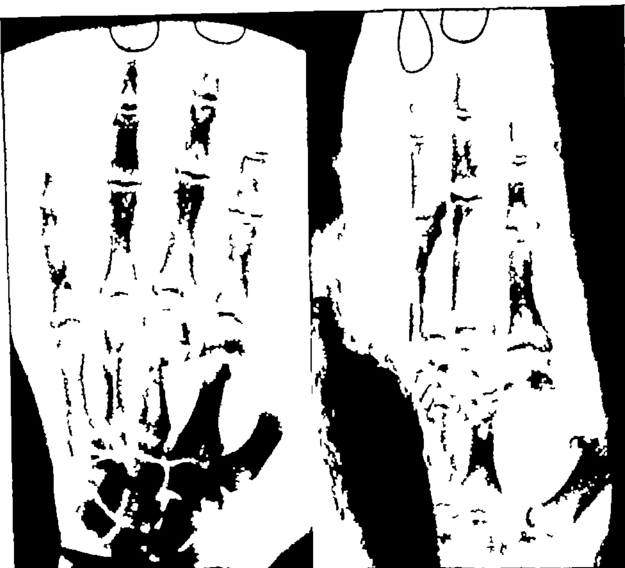


Fig. 388 Fig 389

Figs. 388, 389 Comminuted gunshot fractures of the 1st to 4th metacarpal bones, proximal from the heads. The fragments of the 2nd to 4th are widely separated by wire traction. The head of the 2nd metacarpal shows volar displacement by twice the thickness of the shaft. This prevents union of the fragments. The remaining tendons and joints become useless and the hand has permanently lost its grip

fractures and accidents and should do so and they are offended if they are told that this generalization is incorrect Poor results are usually blamed on the severity of the injury A comparison of Figs I/313, 314 with Figs I/315–321 proves, however, where the responsibility lies

Sooner or later it will come about that effective methods which can be dangerous, if improperly used will not be entrusted indiscriminately to anyone that those few physicians adapted for this type of work—not too many are needed—will be selected for the treatment of accident cases and will be rigorously trained for years in special teaching institutions that special stations for the treatment of the injured will be created and that a special organization will see to it that the injured are brought to these places as soon as possible as I have outlined on pages II/1521–1531

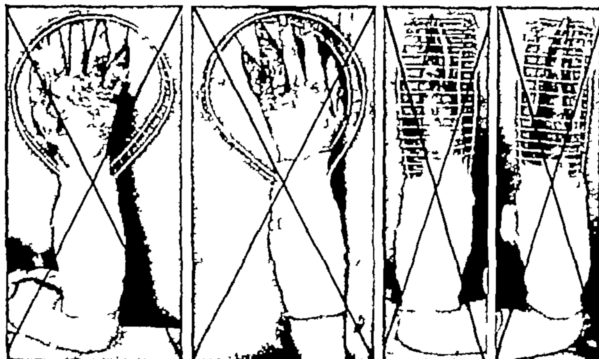


Fig. 382 Fig. 383 Fig. 384 Fig. 385

Figs. 382–385 Banjo splint with wire traction through the tips of all fingers in an injury to the 4th and 5th fingers. The wire pulled out of the thumb The wrist joint is in slight flexion and the metacarpo-phalangeal joints are hyperextended. With this arrangement, not only the injured fingers but also the well ones become permanently stiff and thus the entire hand becomes useless.

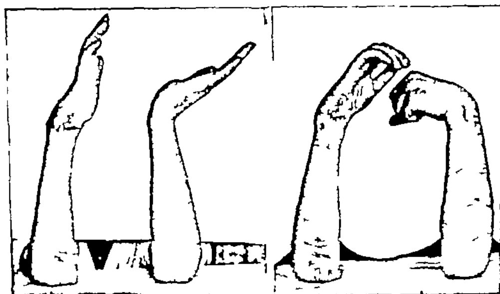


Fig. 386 Fig. 387

Figs. 386 387 End result of a gunshot injury of the wrist with slight involvement of the bone and but slight infection which had been treated for 8 weeks with a banjo splint, in a 21 year-old man, 11 months after injury The wrist stiffened in slight volar flexion and pronation. This causes a hyperextension at the metacarpo-phalangeal joints of the fingers. The hand cannot be closed to a fist. No improvement was obtained by 9 months of after-treatment. If an unpadded dorsal plaster splint had been applied, as in Figs. 429–432 E, 1/1069–1072, the wrist joint would have stiffened in a desirable position or might have retained partial motion, the fingers would have remained freely movable and the treatment could have been concluded after 3–4 months with a good functional result.

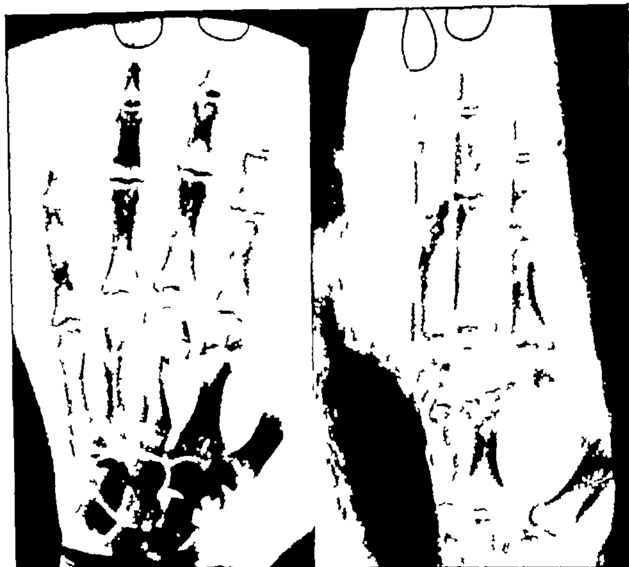


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Fig 390 Fig 391 Fig. 392 Fig 393 Fig 394 Fig 395

June 15 1942 July 25 1942 August 27 1942

Figs. 390, 391 Fracture of the right femur provided with a medullary nail in a 22 year-old blacksmith who was run over The nail is too short. There is a valgus of 6–7° and a recurvation of 10° Treated *elsewhere*.

Figs. 392, 393 Same as Figs. 390, 391 after 6 weeks. A large fuzzy globular callus has formed as in Figs. 1026 E, II/2996 The recurvation and valgus angulations have increased. Around the tip of the nail an area of absorption can be seen in the A-P view The irritative callus and the absorption around the tip of the nail are due to massage and passive motion which were started a few days after the nailing This caused motion of the distal fragment around the short nail, the tip of which ground the cancellous bone.

Figs. 394 395 Same as Figs. 390 and 391 after 10 weeks. The globular callus is increased. Valgus and recurvation now amount to 15° each.

Apparent Stimulation of Callus Formation by the Medullary Nail

Quite some time ago I made the following statement (see page 2 E, 1/5) '*It is particularly desirable to find some means of hastening the formation of callus in order to permit a shortening of the period of fixation and thus to decrease the complications arising from prolonged immobilization* To date we have unfortunately no such means at our disposal. Whatever has been recommended thus far (see page I/167) has proven ineffective Callus formation can only be initiated by a fracture itself or if it becomes sluggish by a new fracture of the bone (therapeutic refracture Beck s drilling Kirschner s splitting or Brandes sawing)

Just as in nailed fractures of the femoral neck it makes no difference in nailed shaft fractures which need no supplementary external support like that in Figs. 108–132 whether the callus formation is somewhat slower or faster because the nail provides a fully adequate substitute prop for the broken bone thus eliminating external props such as casts splints or traction with their ill effects upon motion and



Fig 396 Fig 397 Fig. 398 Fig. 399

August 27 1942 May 5 1943

Figs. 396 397 Same as Figs 394 and 395 immediately after removal of the medullary nail. The fracture line is still plainly visible in the large globular callus.

Figs. 398 399 Same as Figs. 396 and 397 after 8 months. Bony consolidation of the fracture. The valgus position and recurvation may lead to a hyperextension of the knee as in Figs 640 and 641 and after some years the faulty weight bearing may cause an arthrosis of the knee joint.

circulation Since many cases which needed an additional external support have been treated with medullary nailing Küntscher's report that the medullary nail, in addition to providing an outstanding mechanical support, also produced an extraordinary stimulation of the callus formation was received enthusiastically This opinion he supported with apparently convincing X ray pictures In his first report he wrote Experiments on five dogs showed no interference with callus formation, but on the contrary an increase of the same." Later he wrote of "considerable masses of callus and extraordinarily rapid and extraordinarily strong callus formation and A W Fischer mentions an "almost tumor like callus formation "

In his treatise on Callus without Fracture ' Küntscher states

'Of all methods medullary nailing provides by far the most favorable conditions for callus formation. The nail protects the callus from all injurious pulling pushing and shearing strains and permits only the exertion of stimulating pressure. Thus we see, as proven by experience in over 90 cases always extraordinarily marked callus formation, although they showed only narrow fracture lines in which we ordinarily see only slight callus. (By the very nature of medullary nailing the reduction is exact to the millimeter) Furthermore, the other parts of the mechanical unit formed by the bones muscles and joints, suffer no damage because motion is possible immediately after the nailing since the nail by itself replaces the mechanical stability lost by the



Fig. 400 Fig. 401 Fig. 402 Fig 403

June 5 1942 July 13 1942

Figs. 400 401 Leverage fracture of the right femur distal from the middle, provided with a medullary nail in a 60-year-old farmer who was struck by a tree trunk.

Figs. 402, 403 Same as Figs. 400 and 401 after 38 days. A loose globular callus has formed because the patient started weight bearing early and the nail moved in the decalcified bone.

fracture. The damage, therefore is confined to the bone The circulation of the injured limb and of the entire body is not impaired All these circumstances however are not sufficient to explain the formation of such extensive masses of callus as are frequently seen with this method. Rather in studying the X ray pictures we gain the impression that the nail lying in the medullary cavity exerts a marked stimulus In fractures of the middle of the femur for instance callus can be noted as far up as the lesser trochanter This frequently produces the picture of so-called 'periosteal appositions (See fig 1 Zbl f Chir No 19 page 859 1941)

These X ray pictures of Küntscher show a nailed transverse fracture of the femur between the middle and proximal third in a young individual in whom the epiphysis at the femoral neck is still visible The nail is too short and too thin and does not completely fill the medullary space Therefore slight motion occurred with functional use This can be recognized from the fact that the nail bed is widened around the tip as in Fig 405 These motions permitted by a short and thin nail led to the formation of a globular callus as in Figs 390–407 This callus is particularly large and fuzzy because the patient was young That a well-set nail does not produce excessive callus is shown in Figs 608–617

Küntscher further states that a complete filling of the medullary cavity with wires or pins of V 2 A-steel or of glass does not cause the slightest roentgenological changes unless they are impacted into the cavity so tightly that they exert a continuous



Fig 404 Fig. 405 Fig 406 Fig 407

August 15 1942 June 2, 1943

Figs. 404 405 Same as Figs 400 and 401 after 10 weeks. The globular callus has increased in size. The fracture line is still visible. An area of absorption surrounded by a wall of increased density has formed around the tip of the nail The tip, which was at first lying along the anterior wall, is now close to the posterior wall of the bone. This caused a recurvation of 10° and a valgus of 5° The nail penetrated deeper into the bone.

Figs. 406 407 Same as Figs 400 and 401 after one year Bony consolidation of the fracture.

pressure by the strain upon the elasticity of the medullary canal. When he removed the V 2 A wires and the glass rods from the medullary cavity one year later and replaced them with a galvanized iron wire, marked periosteal apposition occurred in a short time, the same occurred after the introduction of curved steel springs Concerning this he writes

'Not bone absorption or a bending of the entire bone developed as expected, but the bone fortified itself against these forces by the formation of a circumferential callus and remained entirely straight. The increase was such that its weight was doubled. Since the mechanical strength of a tube other factors remaining the same is dependent upon its outside diameter (distance from circumference to mechanical axis) this process would represent a marked increase in the mechanical strength Actually however this is the case only to a limited extent because the added bone is at first much softer and the original compacta is partly absorbed. This new bone is so soft that it can be cut with a knife.

'With an elastic medullary nail or simpler yet with an irritating wire we possess the means to produce huge masses of callus as in no other way This stimulus, so to speak, arouses the bone from its quiescence and stimulates unheard-of cell proliferation The method appears simple and without danger since the bone is not exposed to any extent but as in medullary nailing a metal rod is introduced into the medullary cavity percutaneously This method seems entirely safe and in no experiment did callus formation fail to occur

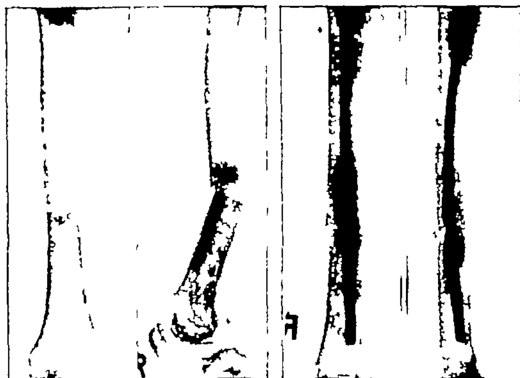


Fig 408 Fig. 409 Fig 410 Fig. 411
March 23 1942 May 8 1942

Figs. 408, 409 Transverse fracture of the right femur in a 17 year-old workman who was caught between an electric hand truck and a wall. Osteopoikily Wire traction for 10 days, then medullary nailing.
Figs. 410 411 Same as Figs 408 and 409 6 weeks after medullary nailing and 10 days after the institution of Swedish massage. Abundant cloudy callus which was not visible before the institution of the Swedish massage.

Like Küntscher Ehrlich A. W Fischer, Heim Sprengell and others, I too believed that in some cases I noticed increased callus formation from the medullary nail. However upon systematically examining complete series of X ray pictures of approximately 500 cases I found that this is not at all the case but that, on the contrary the nail delays callus formation under certain circumstances. This finding constitutes the greatest disappointment that I have experienced as a physician, be cause I had set the highest hopes upon the callus-stimulating effect of the medullary nail Raisch and Schneider arrived at similar conclusions In the meantime a report of Maatz from the clinic in Kiel appeared to the effect that among 300 cases he found increased callus formation only five times in young people only

Küntscher himself states that the fine metals such as the non-corrosive V 2 A steel or glass rods cause no periosteal apposition and that vigorously growing abun dant callus develops only with the use of base metals the callus forming the more abundantly the lower the position of the metal on the scale of elements. This is the chemical effect of salts of metals If iron is used for example the oxidation causes rusting and this rust damages all surrounding tissues Excessive callus may also be caused by excessive pressure as demonstrated by the experiments with curved metal spring leaves One can further observe that periosteal appositions develop wherever the medullary nail plows through decalcified bone (Fig 1191)



Fig 412 Fig 413 Fig 414 Fig 415

July 1 1942 February 10 1943

Figs. 412 413 Same as Figs. 410 and 411 after 8 weeks. Luxuriant callus formation. Calcifications in the muscles. Decalcification of the bones. Knee motion 180–130°

Figs. 414 415 Same as Figs 408 and 409 after 11 months. A valgus angulation of 10° because the nail was already removed after 3 months. Normal calcium content of the bones. Bony consolidation. Bone thickened. Motion of the knee only 180–130° against 180–40° on the left, other joints free. At a follow-up examination after 2 years, the motion showed no improvement.

Since Küntscher uses pure V 2 A-steel for his medullary nails and since they are straight and not curved they can exert neither a chemical nor a mechanical irritation upon the bone as outlined above, provided they set tightly On the lower leg such periosteal appositions are seen sometimes, because the nail is curved For this reason the abundant callus formation as illustrated by Küntscher and Ehrlich in their X ray pictures was at first inexplicable If however, these pictures and many other X ray pictures showing marked periosteal callus formation are studied carefully one will notice that usually strikingly short nails had been used Around the tip of the nail one can notice a cavity with a wall of dense bone This is a sign that the medullary nail moved inside the bone and that this motion destroyed the surrounding trabeculae by a grinding effect (Figs 392–396, 403–405 436–441, 450 451 and 472–475) In the case with abundant callus formation pictured in Figs 392–396 a mechanical stimulus was provided by the fact that the lower fragment could bend against the proximal fragment, because the nail was much too short In the case illustrated by Küntscher the nail is also too short and too thin In his X ray picture after removal of the nail one can see that the nail bed especially at the tip is much larger than the diameter of the nail which proves that the nail moved back and forth inside the bone In Figs 400–405, a comparatively long medullary

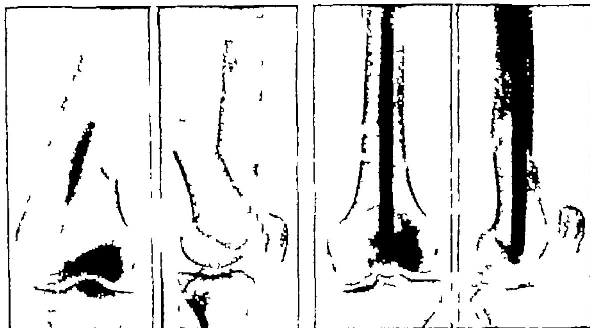


Fig 416 Fig 417 Fig 418 Fig 419

October 27 1942 October 27 1942

Figs. 416, 417 Fracture of the left femur 10 cm. above the knee joint with marked angulation, lateral displacement and shortening in a 63-year-old coachman who was kicked by a horse.

Figs. 418, 419 Same as Figs 416 and 417 after medullary nailing There is a recurvation of 10–12°

nail has been used. However since the patient was about 60 years old the bone was decalcified and the trabeculae formed a wide mesh therefore the tip of the nail traveled as seen by comparing Figs 401 403 and 405 from the anterior to the posterior wall The route traveled by this nail is clearly indicated in the X ray pictures by a dense zone below the tip of the nail Therefore the nail in this case could not eliminate injurious angulatory forces and did not permit the exertion of only favorable axial pressure

Jörg Böhler compared this abundant callus formation very appropriately with the *globular callus* which develops following fine crack fractures of the second and third metatarsal bones. In these the fracture surfaces are in accurate apposition During walking a slight angulation of the distal fragment occurs with every step This continuous mechanical stimulus in which the fracture is exposed to a tensile strain on the plantar surface and to pressure on the dorsal surface causes excessive callus formation (Figs. 1026 1027 E II/2996 2997) In addition to this however all the soft tissues are irritated and such feet remain swollen and painful for many months. If the irritation from the continuous angulation of the fragments is eliminated by a walking cast soon after injury no globular callus will form but the usual absorption of the fracture surfaces and a widening of the fracture line will take place Thus fine fissures are plainly visible after a few weeks. These fracture lines are still clearly evident after 6 weeks yet the fracture is firmly united and weight bearing is possible without pain after removal of the cast (Figs. 1024 1025 E II 2994 2995)

In fissured fractures of the carpal scaphoid likewise an absorption of the fracture surfaces takes place which makes the fracture more plainly visible (see pages I 633



Fig 420 Fig 421 Fig 422 Fig 423
December 30 1942 February 7 1944

Figs. 420 421 Same as Figs 416–419 after 9 weeks. Marked periosteal irritation callus. Several forcible attempts succeeded in correcting the recurvation with a Schultze osteoclast (Figs. II/2129 2130 and 933 E, II/2745) and with a Phelps-Gocht (Fig 934 E, II/2746) but this caused additional damage to the muscles which had been torn by the original marked displacement.

Figs. 422, 423 Same as Figs. 416–419 10 months after removal of the medullary nail and 15 months after the injury Knee 170–80° against 170–65° on the right. Other joints actively free.

634) In this case, however, omission of immobilization does not cause increased callus formation but a pseudarthrosis, because the periosteum is not covered by muscles For the same reason periosteal appositions occur only rarely on the tibia as shown in Figs. 448 and 450 in which pseudarthrosis developed later (Fig 455) In fractures of the humerus which is surrounded by a thick muscular cuff, excessive callus formation is not uncommon as shown in Figs. 1010–1031

That the chemical effect of corroding medullary nails causes periosteal apposition is shown by the cases of Ehrlich (Figs 198, 199), Sprengell (Figs 273–276) and Figs 264–272

Figure 198 shows periosteal appositions on the medial side at the level of the tip of the nail and Fig 199 shows an area of absorption of the cortex on the lateral side of the tip of the nail as a sign of corrosion damage As Ehrlich communicated to me after its removal this nail showed a corroded tip similar to the nail of Sprengell (Fig 274) In both of Sprengell s cases, slight periosteal appositions can be noted in the region of the corrosions. The absorption of the cortex however, in the region of the corrosions, is much more pronounced In the second case of Sprengell a sinus developed later at the site of the corrosion. I have also seen this in other cases with corrosion damage Most patients with rust damage have 'drawing' pains and cannot bear weight on the leg very well nor can they use the arm very much as long as the corroded nail remains For this reason the intentional use of corroding ma

terial or of irritating wires must be omitted The damages which may result from these have been known to us for a long time from nailed hip fractures (Figs. II/1782–1806)

Irritative callus can also be produced by other mechanical means as shown in the two following cases.

In Figs 410–413 the application of Swedish massage with forceful kneading and tapotement of the muscles caused periosteal callus formation and decalcification of the bones. There is no indication that the nail which was too short had moved in the bone as in Figs. 392–405 In spite of the youth of the patient (17 years), this irritative treatment led to a permanent and marked restriction of the motion at the knee joint, although the fracture was only slightly displaced and rather far removed from the knee.

In Figs. 416–423 marked periosteal appositions developed because the muscles were torn by the marked displacement of the fragments and because they were further damaged by the repeated forcible attempts to bend the bone Furthermore this case seems to show a particular predisposition to increased bone formation as seen by the marked callus cap (Figs. 424–427) The medullary nail did not move because it had been driven sufficiently deep into the bone Although the man was 63 years old, only a minimum restriction of motion in the knee joint developed, because no further injurious influences were added after the attempts at bending the nail in the first few days.

Irritative callus is a pathologic tissue and even after 10 weeks or later one can see that the fracture line penetrates through the periosteal appositions like a beginning pseudarthrosis (Figs. 394–396 and 404, 405) Any limb with an irritative callus is strikingly sensitive and sometimes it shows a local swelling A W Fischer reported that in a case with an almost tumor like callus marked secondary angulation of the femur occurred 8 weeks after the nail had been removed

Summary A medullary nail made of V 2 A steel does not stimulate callus by its mere presence in the medullary canal If it is too short or too thin it cannot prevent injurious pulling, shearing and pushing strains and therefore an irritative callus is produced similar to the globular callus in crack fractures of the second and third metatarsals. Since periosteal irritative callus is inferior and soft and does not contribute to a rapid firm union of the fracture but, on the contrary delays it, one must try to prevent its formation by the use of sufficiently long and sufficiently thick medullary nails and one must not try to produce it artificially by the use of corrosive material.

The Callus Cap

Sometimes a peculiar formation can be noted around the head of the medullary nail which Küntscher called a callus cap (Figs. 424–429) He claims that it is produced by droplets of fat marrow running along the groove of the nail into the subcutaneous tissue causing bone formation upon contact with the fibrous tissues.

The callus cap is comparatively rare I have seen it only in a few fractures of the femur and once I found a slight indication of it in a humerus, but never in a lower leg or forearm fracture, although during any medullary nailing a considerable amount

of marrow can be seen oozing through the groove of the nail Therefore this spilling of marrow does not seem to be the cause Perhaps it is caused by a constitutional peculiarity as in Figs 416–426, or perhaps some muscle tissue is crushed between the head of the nail and the driving punch, and bone forms in this crushed muscle tissue similar to myositis ossificans following dislocations of the elbow The histologic findings on pages 137–138 speak for this interpretation in that striated muscle fibres were found between the islands of cancellous bone The fact that a callus cap never develops on the leg, ulna or radius seems to prove this opinion, because in these locations there are no muscles, yet bone marrow is always spilled in these places too

The following histologic findings of the callus cap shown in Figs 424–429 are taken from the thesis of Dr Emilie Mayer



Fig. 424 Fig. 425 Fig. 426

Figs. 424 425 Unusually large callus cap of Figs. 422, 423 removed from the medullary nail and placed upon it. Natural size.

Fig. 426. X-ray picture of Fig 425 reduced.

The histologic examination (carried out in the Institute for Pathology in Vienna, Director Professor Dr Chiari) revealed

"A structure shaped approximately like the head of a mushroom, firm in consistency about 4.5 × 4 × 2.5 cm. in size, showing dense fibrous tissue on the outer side and a cone-shaped prominence (a) in one area of the surface 10 × 15 × 7 mm. in size. A cut through the middle of the prominence and the entire structure shows a round cavity (b) approximately at the center about 1.5 cm. in diameter with an opening of 15 × 10 mm. (c) on the opposite side. The inner surface of this cavity is lined with a soft whitish red tissue (d) in concentric layers with a maximum thickness of 5 mm. This is surrounded by tissue of bony consistency (e) The wall opposite the opening is only 1 mm. thick for an area of 1 cm. An overall section shows the cavity lined with fibrinous masses and with scattered leucocytes. This fibrous tissue is surrounded by cancellous bone tissue with partly fibrous marrow, partly fat marrow The trabeculae next to the cavity show an approximately concentric arrangement around the cavity wide osteoblastic seams and contain fibrous marrow Toward the periphery of the structure cancellous bone was found with irregularly arranged trabeculae of varying size, showing many old cement lines with predominantly fat marrow, and in one place striated muscle fibres between the cancellous remnants. The arrangement of these trabeculae shows no definite relation to the cavity They are surrounded on the outside by fibrous scar tissue which gradually merges into bundles of striated muscles without a sharp line of division. At the entrance to the cavity mentioned before, several small islands of cartilage are found which are in a stage of ossification. Inflammatory processes are represented only in the form of scattered lymph cell infiltrations.



Fig 427



Fig 428

Fig. 427 Saw-cut through the callus cap of Figs. 424–426

Fig. 428. X-ray picture of a callus cap from the article by A W Fischer and Maatz (Arch. f klin. Chir 203 No. 4, 1943)

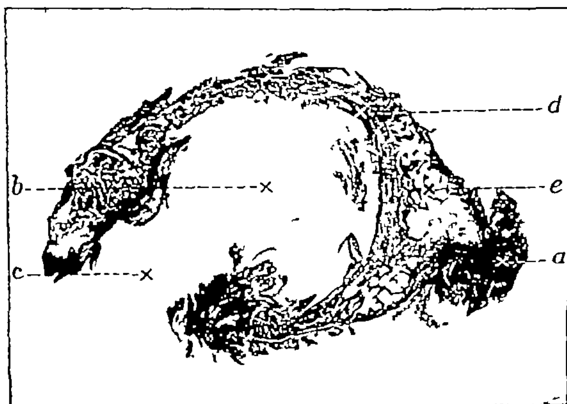


Fig. 429

Fig. 429 Microscopic section through the callus cap of Figs 424–427

"This histological picture indicates that a partly cartilaginous partly bony callus formed around the end of the nail whereas the old irregular trabeculae described above and located most superficially appear to be derived from pre-existing bone

If the nail protrudes more than 3 cm from the greater trochanter one may some times see a callus ring instead of a callus cap (Figs. 167 198) Sometimes a bursa

forms around the end of the nail like that over the head of the hip nail This bursa is the larger, the further the nail protrudes. Sometimes it is filled with rice bodies (Fig 692) Occasionally one may find calcium deposits in the wall of the bursa.

Inhibition of Callus Formation by the Medullary Nail

The expectation that a medullary nail of non corrosive material accelerates and even intensifies callus formation has unfortunately not been fulfilled On the contrary, a careful follow up of many cases has revealed that callus formation is sometimes delayed or even completely stopped by the medullary nail on the tibia and on the forearm bones as shown by Figs 430–459 For this reason, during our first year of the use of the medullary nail the average duration of treatment of fractures of the leg was twice as long as before The same observation was made by A W Fischer, Raisch and Schneider

In the compound fracture of the lower leg shown in Figs. 430–441 the cause of non union was a series of technical mistakes Instead of eliminating the slight lateral displacement of Figs 430 and 431, the fragments of the tibia were separated by 10 mm and slightly angulated (Figs 432, 433) In other words a *dislocatio ad longitudinem cum distractione* was produced, i e that dangerous displacement which prevents or completely stops callus formation (see pages 106–118) Because of the valgus position the gap in the fibula was much smaller than in the tibia. It therefore soon filled with bone, whereas on the tibia a pseudarthrosis developed (Figs 434 435) Not only the fibula but also the medullary nail had a locking effect upon the fragments of the tibia The continuous strain upon it finally led to a fatigue fracture of the nail When the fragments of the broken nail were removed, the fibula which was too long was osteotomized obliquely but was not shortened In anticipation of the callus-stimulating effect of the nail, the fracture surfaces of the tibia were not freshened. Again too short a nail was chosen (Figs 436, 437) Therefore the fragments had play However, no irritative callus formed as on the femur (Fig 392–407) but an abscess developed after 4 months. The motions of the nail in the medullary cavity destroyed the cancellous bone (Figs 438–441) When the double locking action of the fibula and the medullary nail were eliminated 17 months later by a resection of a 2 cm piece of the fibula and by removal of the medullary nail, bony union of the tibia followed 4 months later (Figs 440, 441)

Still more interesting is the course of the compound leg fracture shown in Figs 442–459 The reduction was excellent but the nail was too short and too thin (Figs 444 445) Because of large wounds the patient remained in bed in a supplementary plaster cast for 7 weeks to prevent disturbing the wound The position of the fragments was still very good but there was no trace of callus formation because the medullary nail in spite of its shortness, had prevented an approximation of the fragments (Fig 446 447) The patient was permitted to get about without a plaster cast under the assumption that the fracture was after all this time fit to bear weight. Ten weeks later one can see periosteal callus appositions on the medial side, in the lateral view the fracture line has become distinctly visible (Figs. 448 449) X ray pictures taken 7 months after the injury were somewhat indistinct and appeared to



Fig. 430 Fig. 431 Fig. 432 Fig. 433 Fig. 434 Fig. 435
September 8, 1941 September 8, 1941 May 11 1942

Figs. 430, 431 Compound transverse fracture of the left lower leg in a 21 year-old workman who was caught in an elevator

Figs. 432 433 Same as Figs 430 and 431 after wound excision and medullary nailing. The fragments are gaping 10 mm. From the proximal fragment a wedge was broken off on the lateral side. The nail is markedly bent. The distal fragment is angulated laterally Wound healed without disturbance.

Figs. 434 435 Same as Figs. 430–433 after 8 months. Since the fragments were not impacted the fibula healed with a lengthening and a pseudarthrosis developed on the tibia. The nail shows a fine crack.

indicate an obliteration of the fracture On closer inspection however one can see an area of absorption around the tip of the nail, a sign that it moved in the bone (Figs. 450 451) Under the assumption that the fracture was firmly united the nail was removed Four weeks later a distinct pseudarthrosis gap could be seen in the lateral view (Fig 453) and after another 6 weeks the gap had widened in the anterior portions (Fig 455) An osteotomy of the fibula was performed and another medullary nail was inserted of sufficient length and thickness Thereupon callus formed rapidly (Figs. 456 457) and 16 months after the injury the fracture was finally firmly united (Figs. 458 459)

These two cases show that the medullary nail does not stimulate callus formation by its mere presence in the medullary canal. If it is too short or too thin as in Figs 430–459 only slight irritative callus will form on the tibia (Figs. 448–450) and in contrast to the femur (Figs. 392–407) and to the humerus (Figs 1010–1031) this slight callus cannot prevent a pseudarthrosis

To avoid such serious disturbances in fractures of the tibia the nail used must be sufficiently long and thick and the fragments must be immediately impacted properly If it is noticeable after a few weeks that callus formation is inadequate the fibula must be osteotomized early to prevent its locking effect.



Figs. 436, 437 Same as Figs 430–433 After 9 months, the fracture of the tibia was exposed. Both pieces of the nail were removed and a new nail was inserted. Again it is too short. Good alignment.

Figs. 438 439 Same as Figs. 430–433 5 months after insertion of the new nail and 2 months after osteotomy of the fibula in the upper third. An abscess developed at the fracture site. The tibia shows varus angulation and antecurvation of 10° each. The nail destroyed the distal part of the medullary cavity Marked decalcification.

Figs. 440 441 Same as Figs 430–433 after 21 months. After 17 months, a 2 cm. piece was resected from the fibula and the nail was extracted. This was followed by bony union with varus angulation of 12° Marked decalcification. The cavity in the tibia in which the nail moved is still plainly visible.

Figures 460–467 show a serious leverage fracture of the forearm in which the radius was nailed 4 weeks after the injury Since callus formation was marked on both bones (Figs. 462 463) the supplementary plaster cast was removed one month after the nailing Due to increased use, a pseudarthrosis of the ulna developed (Figs 464–467)

Callus Formation in Medullary Nailing of Pseudarthroses

Medullary nailing of pseudarthroses was followed by many failures because some surgeons believed that the mere presence of the nail in the medullary cavity was sufficient to stimulate callus formation without freshening of the fracture stumps. This is unfortunately not the case as shown in Figs 468–479 972–983, 1172–1179, 1186–1197 1204–1221

Similar to the use of the three flanged nail in pseudarthrosis of the neck of the femur the medullary nail constitutes a great progress in the treatment of pseudarthrosis of the shaft of the femur because it enables us, with proper technique, to unite the fragments immovably which is impossible with any other method. How



Figs. 442 443. Compound fracture of the right lower leg with marked displacement in a 33-year-old work man who was struck by a heavy load as it was being lowered by a crane. The badly soiled bone protruded 6 cm. through a 14 cm. long wound.

Figs. 444, 445 Same as Figs 442 and 443 after excision of the wound, insertion of the nail and skin suture The two rubber drains are plainly visible.

Figs. 446, 447 Same as Figs. 442–445, after 7 weeks. Wound healed without disturbance. The frag ments are in excellent apposition. No callus can be seen. Has not walked yet.

ever, there are great differences between these two types of pseudarthrosis. If a non union of the neck of the femur is properly reduced by suitable traction and inward rotation without exposure of the fracture and without freshening of the fracture surfaces and if the fragments are then united by a nail, bony union usually occurs even if the fracture is of many years standing as shown in Figs 844a–845b E, II/1818–1870 This is possible only because we are dealing with cancellous bone.

If a nail is used in a shaft pseudarthrosis without also freshening the fracture stumps absolutely no callus will form as shown in Figs. 470–473 When both fragments were freshened superficially after 3 months and united with 2 supplementary wire sutures (Figs 474 475) no callus formed because the freshening was insufficient and because the nail was too short and too thin In spite of the nail and the wire sutures, motion between the fragments was possible as shown by the large cavity around the tip of the nail (Figs. 474, 475) and by the fracture of the nail (Figs 476 477) Whereas, in a fresh fracture constant motions and not the presence of the medullary nail cause extensive periosteal appositions as in Figs 392–397, 1010–1023 and 1024–1031 this does not happen with pseudarthroses In these, the fragments will not unite unless they are thoroughly freshened by a transverse or oblique saw-cut and firmly united by a nail of sufficient length and thickness with additional longitudinal wire sutures (Figs. 478 479) A critical review of nailed pseudarthroses of the tibia, humerus and forearm reveals that the nail offers no advantages over other methods but occasionally presents disadvantages. We therefore do not use the nail for these bones.



Fig 448 Fig 449 Fig 450 Fig 451 Fig 452 Fig. 453

April 3 1942 June 26 1942 July 24 1942

Figs. 448, 449 Same as Figs. 442–445 after 17 weeks. In the A P view periosteal irritation callus can be seen in the lateral view a widened fracture line.

Figs. 450 451 Same as Figs 442–445 after 7 months. The periosteal irritation callus has increased The lateral view is somewhat blurred and the fracture line therefore indistinct The nail was removed under the assumption that the fracture was firm.

Figs. 452, 453 Same as Figs 450 and 451 4 weeks after removal of the medullary nail. The lateral view shows a wide pseudarthrosis line



Fig 454 Fig 455 Fig 456 Fig. 457 Fig. 458 Fig 459

September 9 1942 February 15 1943 March 25 1943

Figs. 454 455 Same as Figs 442–445 after 9 months. In the A P view the fracture appears firm. The lateral view shows, however that the gap of the pseudarthrosis has widened.

Figs. 456, 457 Same as Figs 454 and 455 4 months after insertion of another longer and thicker medullary nail. The pseudarthrosis begins to obliterate.

Figs. 458 459 Same as Figs 442–445 immediately after removal of the nail and 16 months after injury Bony union with varus angulation of 10° If 2 circumferential wire sutures had been used in this fracture as in Figs. 902–909 instead of a medullary nail this man could also have left the hospital after 4 weeks with a walking cast and the fracture in all probability would have healed firmly in 10 weeks instead of in 16 months.



Fig. 442 Fig. 443 Fig. 444 Fig. 445 Fig. 446 Fig. 447
December 5, 1941 December 5 1941 January 21 1942

Figs. 442, 443 Compound fracture of the right lower leg with marked displacement in a 53-year-old workman who was struck by a heavy load as it was being lowered by a crane. The badly soiled bone protruded 6 cm. through a 14 cm. long wound.

Figs. 444 445 Same as Figs 442 and 443 after excision of the wound, insertion of the nail and skin suture The two rubber drains are plainly visible.

Figs. 446, 447 Same as Figs 442–445 after 7 weeks. Wound healed without disturbance. The fragments are in excellent apposition. No callus can be seen. Has not walked yet.

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Fig. 464 Fig 465 Fig. 466 Fig. 467
July 1 1942 May 11 1944

Figs. 464 465 Same as Figs 462 and 463 after 5 weeks. The callus at the ulna has become absorbed as in Figs. I/864–871 and I/966–971 The calcium content of the ends of the bones has improved.
Figs. 466, 467 Same as Figs 460 and 461 after 2½ months and 1 year after removal of the nail At the ulna a definite pseudarthrosis developed Calcium content of the bones is normal otherwise. Good function.

buried This danger is the bugaboo with the old operative treatment of fresh closed fractures with exposure of the fracture field It has frequently been followed by loss of life loss of limb or loss of function (see pages 82–85E) It is to the outstanding credit of Küntscher to have shown that by means of his medullary nail which is inserted through a small incision far from the fracture site the frag ments can be joined solidly with amazing firmness without exposing the fracture field. All these circumstances greatly reduce the danger of infection and only comparatively few cases of serious wound infection have been reported with this method, and were due as a rule only to errors in indication and technique

Local inflammation at the nailing site Occasionally local inflammation occurs at the site of insertion A. W Fischer reports it in six out of 67 femur fractures and in one of 73 leg fractures We have observed it twice in 38 closed femur fractures and three times in 67 closed leg fractures The inflammation and suppuration usually disappear in a short time after the removal of the sutures or as a rule rapidly after the removal of the nail *As long as any inflammation is evident at the site of insertion one must be very careful with ambulation and weight–bearing, otherwise the infection may creep along the medullary nail into the medullary cavity*



Figs. 460 461 Leverage fracture of both bones of the right forearm with a 5 cm. wedge fragment on the ulna in a 37 year-old foreman whose arm was caught in a machine

Figs. 462, 463 Same as Figs. 460 and 461 after 3 months, and 2 months after medullary nailing, and 1 month after removal of the cast. The nail fits well. Marked callus on both bones towards the interosseous space Marked decalcification of the ends of the ulna and radius. Begins to work.

It is entirely erroneous to expect callus production from the nail when used in defect pseudarthroses, assuming that the gap will be filled Yet I found a number of such unsuccessful attempts (Figs 972–983 and 1172–1179) In no case had the slightest callus ever formed and usually the nail broke If skin conditions are favorable such gaps can be bridged only with bone grafts or, if bad scars are present, by the implantation of the fibula into the tibia as shown in Figs II/2606–2609

Even if an osteotomy is performed the fragments must be accurately coapted by the removal of sufficiently large wedges of bone with saw or chisel. If the bone is merely sawed transversely as in Figs 252–255 the nail may break (Figs 256 257) If a new nail is not inserted in time (Figs 258–261) a pseudarthrosis may develop

INFECTION AFTER MEDULLARY NAILING

Infection following Closed Nailing

Häbler reported 1 5% infections in closed nailings and 11% infections in open nailings

The crucial problem in the operative treatment of fractures is the danger of infection and not the question of what type or size of foreign body is being



Fig 464 Fig 465 Fig 466 Fig 467

July 1 1942 May 11 1944

Figs. 464 465 Same as Figs 462 and 463 after 5 weeks. The callus at the ulna has become absorbed as in Figs. I/864–871 and I/966–971 The calcium content of the ends of the bones has improved.

Figs. 466 467 Same as Figs 460 and 461 after 27 months, and 1 year after removal of the nail. At the ulna a definite pseudarthrosis developed Calcium content of the bones is normal, otherwise Good function.

buried This danger is the bugaboo with the old operative treatment of fresh closed fractures with exposure of the fracture field It has frequently been followed by loss of life, loss of limb or loss of function (see pages 82–85E) It is to the outstanding credit of Küntscher to have shown that by means of his medullary nail which is inserted through a small incision far from the fracture site the fragments can be joined solidly with amazing firmness without exposing the fracture field. All these circumstances greatly reduce the danger of infection and only comparatively few cases of serious wound infection have been reported with this method, and were due, as a rule only to errors in indication and technique

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Fig 468 Fig 469 Fig 470 Fig. 471 Fig. 472 Fig 473

January 7 1942 January 9 1942 April 1 1942

Figs. 468 469 A 1 year old oblique pseudarthrosis of the right humerus in a 44-year-old forester who was injured by a fall in rocky terrain. Treated *elsewhere* with an airplane splint and excessive continuous traction.

Figs. 470 471 Same as Figs 468 and 469 after open medullary nailing. Relying upon the callus-stimulating effect of the medullary nail the operculated ends were not freshened. The nail is too thin and too short. A drain was inserted postero-laterally Because of the apparent stability of the fracture after nailing no cast was applied.

Figs. 472 473 Same as Figs 468–471 after 3 months. No trace of callus formation can be seen. Large cavity around the tip of the nail which moved back and forth between the walls of the bone with motions of the arm and ground the trabeculae to bits.

Local infection at fracture site In a closed comminuted fracture of the femur (Figs. 649–656) infection of the fracture developed because the nail was inserted through a skin defect following a third degree burn. The mistake in this case was that the nail was inserted twenty four hours later when the skin was already infected and that the skin incision was closed The fracture was exposed after three weeks by two incisions. Several sequestra separated from the third fragment Bony union with good alignment and 1 cm shortening ensued If the nailing had been performed on the first day and if the wound had not been closed tightly the course would probably have been more favorable Yet the nail greatly facilitated the nursing care of the extensive burns As a rule however nailing must be omitted in cases of burns because the course is rarely as favorable as in this case

Chronic osteomyelitis Serious permanent damage was found in the following patient.



Fig. 474 Fig. 475 Fig. 476 Fig. 477 Fig. 478 Fig. 479

April 3 1942 March 5 1943 June 6, 1943

Figs. 474 475 Same as Figs 472 and 473 after the second operation in which the fracture stumps were exposed and freshened without removing the nail The opercula were removed. Both fragments were united additionally with 2 circumferential wire loops. A shoulder spica was applied for 3 months.

Figs. 476, 477 Same as Figs 474 and 475 after 11 months. Following the removal of the cast, the patient could use the arm well but 6 months later he felt a snap in the arm following a vigorous motion and there was again abnormal motion at the original fracture site. The nail broke.

Figs. 478, 479 Three months after the third operation. The fracture was again exposed, both pieces of the nail and the 2 wires were removed. Both fracture stumps were freshened transversely in the healthy area. A double nail, thicker and sufficiently long was then inserted which reached into the head of the humerus. Two additional longitudinal wire sutures were applied and a shoulder spica for 12 weeks. Bony union. If in this case, the fracture stumps had been freshened Z-shaped or obliquely on January 7 1942 and united with 2 wire sutures, and a shoulder spica applied instead of a medullary nail the pseudarthrosis would probably have healed in 3 instead of in 17 months.

Case A 20-year-old female suffered a leverage fracture of the left femur on Sept 16 1941 (Figs 480 481) and a contused laceration 5 x 15 cm on the inner posterior surface below the knee Debridement of wound suture and Steinmann pin traction through the tibial tuberosity followed. The wound healed without disturbance On Oct 4 i.e. after nineteen days, medullary nailing was performed without a reducing apparatus requiring hours of 'wrestling X ray pictures (Figs 482 483) show that fragments 44 and 55 mm. long broke off the anterior surface of the proximal and distal fragments A splinter of cortex, 35 x 16 x 4 mm. was driven by the nail into the metaphysis ahead of the tip On Oct 10 slight temperature elevation to 37 5°C and on Oct 23 up to 38 7°C was recorded Fluctuating area behind the greater trochanter was noted Two incisions were made and a drain inserted for drainage of the pus whereupon the temperature subsided On Oct. 31 again temperature rises to 39.3°C Fracture not tender Wound at the knee healed without reaction Up to Nov 18 recurrent temperature rises to 39°C Marked purulent discharge which gradually subsided and rapidly disappeared after removal of the nail on Feb 2 1942 The patient was discharged on April 3 1942 with healed wounds and knee-



Fig. 468 Fig. 469 Fig. 470 Fig. 471 Fig. 472 Fig. 473
January 7 1942 January 9 1942 April 1 1942

Figs 468 469 A 1 year old oblique pseudarthrosis of the right humerus, in a 44-year-old forester who was injured by a fall in rocky terrain Treated elsewhere with an airplane splint and excessive continuous traction.

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Chronic osteomyelitis Serious permanent damage was found in the following patient



Fig. 484 Fig. 485 Fig. 486 Fig. 487 Fig. 488 Fig. 489

February 2 1942 June 5 1943 June 10 1944

Figs. 484 485 Same as Figs 480 and 481 immediately after removal of the nail and 4 months after nailing. The fracture shows bony union without shortening and with 10° recurvation. The calcium content markedly reduced in the region of the knee joint. The splinter of cortical bone which the nail had driven into the metaphysis, is plainly visible

Figs. 486, 487 Same as Figs. 480–485 21 months after injury The cortical splinter in the metaphysis is still distinctly discernible Decalcification Extensive periosteal apposition over the entire femur especially on the medial and anterior aspect of the distal quarter of the femur due to an inflammatory flare-up in the medullary canal.

Figs. 488, 489 Same as Figs 480–483 after 33 months. The entire femur is sclerosed as in chronic osteomyelitis

purulent discharge It stopped after the removal of the nail and the wound closed X ray pictures (Figs 484, 485) show no sign of inflammation in the form of periosteal appositions or of sequestra One year after removal of the nail and after the wound had healed a post partum inflammation developed which was interpreted as a thrombophlebitis It must be connected with the previous suppuration During its course the old focus of infection in the bone flared up especially around the splinter of cortex which had been displaced into the metaphysis Extensive periosteal appositions developed in the region of the metaphysis (Figs 486 487), also an effusion in the knee joint and a sinus formed During the subsequent months the course and symptons of the disease were the same as in a chronic genuine osteomyelitis with periosteal appositions, abscesses sequestra and sclerosing of the bone

This series of symptoms developed because the medullary canal was blocked at the fracture site and at the nailing site when the inflammation flared up To avoid such late complications nailing should be performed only if an adequate reduction



Fig 480 Fig. 481 Fig. 482 Fig 483

September 16 1941 November 8, 1941

Figs. 480 481 Leverage fracture of the left femur below the middle in a 20-year-old youth who was struck by a heavy rock and suffered also a 15 cm. long and 5 cm. wide transverse wound postero-medially below the knee Tibial pin traction. Wound healed without disturbance.

Figs. 482 483 Same as Figs 480 and 481 5 weeks after the medullary nailing performed *elsewhere*. On the anterior surface of both fragments, several slivers broke off 44 mm. and 45 mm long. Between the knee joint and the tip of the nail there is a bone splinter 35 x 16 x 4 mm. in size. Recurvation of 10°

motion from 180–75 The muscles were still much weaker than on the well leg She was then up and around without discomfort On March 22 1943 i e. one year after the closure of the wounds in the trochanter region, a post-partum phlebitis developed with which she was bed ridden for three months Then a sinus developed on the inner side of the left femoral condyle, discharging serous secretion The knee was slightly swollen and limited from 160–105° X ray pictures (Figs 486 487) showed extensive periosteal appositions over the entire femur especially on the medial and anterior surface above the knee joint. In August, 1943 temperature rises recurred. The thigh was swollen, reddened and tender at the fracture site. A fluctuating area on the inner and outer side was incised The bone was surrounded by pus In the depth roughened bone could be palpated. In November 1943 again marked swelling and fever X-ray pictures showed marked increase of periosteal appositions along the entire femur and several periosteal and central sequestra between the middle of the femur and the knee joint. These were removed operatively On June 10 1944 two sinuses were still draining The entire femur bone is sclerosed as after an acute genuine osteomyelitis (Figs 488 489) Knee motion 160–130°

In this case reduction and nailing performed *elsewhere* consumed nearly four hours During this long period asepsis was probably disturbed The infection which took a more serious course than usual was at first apparently confined to the nailing site and the surrounding area. It probably spread later to the entire medullary canal as indicated by the persistent rise in temperature and the marked

large as a medullary nail may lead to serious disturbances even after 3 weeks of initial well being, even if the fracture had not been exposed and if the nailing was done through only a small wound In retrospect, one must say that the use of the nail in this case was not indicated In the future we will not nail fractures which show blebs as an indication of serious circulatory interference Since this fracture was sixteen days old, a walking cast could have been applied one week later without operation and the patient would have been able to walk about After the nailing he was kept recumbent for fear of redisplacement in spite of the nail When fever developed on the 20th post-operative day, it would have been sufficient to remove the sutures at the nailing site, exposure of the fracture and the removal of the nail would not have been necessary The angulation of 12° could have occurred even if the nail had remained in situ, as evident from the X ray pictures of A W Fischer, Stotz and our own experiences Even considering all these circumstances I must say that I never had seen such serious complications before In more than 2,000 closed leg fractures which I treated without operation, such complications never occurred In our 146 fresh compound leg fractures reported by Ehalt, we have never noticed the spread of the infection to the medullary cavity or to the femur

Since we are never safeguarded against such complications following medullary nailing, the indication for this operation must be made very cautiously The contra indications enumerated on pages 8–10 must be carefully observed If marked swelling with blister formation is present, medullary nailing should be omitted

Fatal infections have been reported to date only by A W Fischer, Ehalt, Krenslehner and Stotz The case reported by A. W Fischer had a severe compression fracture of the twelfth dorsal vertebra, a penetrating wound of the right knee joint extensive hematomas on both thighs and a closed fracture of the left lower leg The leg was nailed six days later when it appeared that the knee joint wounds were healing without complications. The nailing was performed without difficulty After 4 days septic temperature rises developed and in the following days the right knee joint had to be opened widely because of suppuration. At the same time it was apparent that the hematomas on the thighs and also the fracture of the left lower leg were infected The same staphylococcus was cultivated from all the infected areas. The man died after a few days

From this observation one must conclude that nailing must not be carried out until larger wounds on other parts of the body are already completely healed, because the commotion which necessarily accompanies the reduction and nailing of the fracture is so detrimental to fresh wounds that they are apt to become infected

Krenslehner nailed a transverse fracture of the femur in a five year-old boy on the tenth day because lateral displacement persisted On the next day there was high fever and on the following day the child died with symptoms of acute osteomyelitis.

The case of Ehalt concerns a 63-year-old man who suffered a fracture of the lower leg when he was struck by a falling tree trunk. The next day upon admission the

apparatus is available so that the reduction can be performed in a short time and asepsis will not be disturbed by numerous attempts at reduction during the operation

The observation that a true osteomyelitis may develop one year after closure of the wounds is of fundamental importance because in some cases it may, as in genuine acute osteomyelitis, recur in the same way, after years or decades For this reason I believe that one should be very careful in using the medullary nail in infected fractures because germs are thereby spread into the medullary canal. As a rule, the inflammation is not very marked in the beginning because the medullary canal is not under pressure as long as the fracture and nailing site are still open After the fracture is healed and the nail has been removed, the medullary canal is again closed and under certain circumstances a cold, over-exertion, tonsillitis or other inflammatory diseases a similar inflammatory process in the bone may be precipitated as in this case It will not be possible for many years or decades to determine the percentage of cases in which such late complications arise I am, however, of the opinion that these dangers should be seriously weighed For this very reason I have always rejected the medullary nailing of infected fractures.

Amputation In our 67 closed leg fractures, local inflammation at the nailing site developed three times these subsided in a short time without further disturbances after removal of the sutures. In the 67th case a severe phlegmonous infection developed requiring amputation of the leg

Case A 59-year-old man suffered a short spiral fracture of the tibia on Jan 24 1944 between the middle and the lower third with rotation angulation shortening and lateral displacement by full thickness of the shaft as well as a fracture of the fibula 6 cm above the tip of the outer malleolus Pin traction was applied to the os calcis at first with 3 Kg., later with 4 Kg Due to the marked original displacement marked swelling and large tension blebs developed Since the lateral displacement could not be completely corrected, a closed medullary nailing was performed on Feb 8 1944, i e., sixteen days after the injury Two days later the temperature rose to 37.8°C. Then he was afebrile and without pain up to Feb 26 On Feb 27 i e. twenty days after the nailing a high fever and severe pain developed without apparent cause even though he had not been out of bed The nailing site was swollen and red. After removal of the sutures pus discharged. The fracture site was somewhat tender When the temperature did not subside, I had the fluctuating area over the fracture incised on Feb 29 Only blood with fat droplets was found but no pus A plaster cast was applied and the nail was removed. Temperature subsided to below 37°C and remained normal until March 22 although suppuration from the nailing site continued. Then sudden rise of temperature to 39°C and pain over the fracture of the fibula An abscess had formed in this region which was ready to break through and much pus was evacuated through a stab incision. This was again followed by an afebrile period. On April 18 suppuration from the nailing site and from both wounds was only slight. On April 24 the leg was straightened because a varus angulation of 12° had developed. Thereupon the temperature again rose to 39°C with marked swelling of the entire lower leg On April 29 an extensive cellulitis was incised Nevertheless septic temperatures continued numerous sloughs of necrotic tendon and fascia separated and the infection spread to the femur requiring further incisions on May 10 Thereupon temperature fluctuations between 37.5–38°C Since the patient was greatly debilitated by the prolonged suppuration and since the leg had become useless through the loss of large areas of tendons and fascia and because the bone was surrounded by pus the leg was amputated through the thigh on May 20 Thereafter a gradual recovery was made.

This case history shows that the introduction and burying of a foreign body as

macrophages and many cells containing coarse pigment indicating transformation of the marrow into scar tissue No phlegmonous inflammation of the medullary cavity was evident

Stotz states "Nailing is responsible for the development of the cellulitis around the knee, whether it spread from infection of the ulcer at the fracture site or from infection at the nailing site, although it was obviously an unfortunate chain of complicating circumstances in a patient with lowered resistance The infection of the colon was undoubtedly a metastatic process from septicemia "

This unfortunate result must lead to the conclusion that in fractures of the lower leg with varicose changes in the skin the medullary nail should never be used (see page 9)

In summarizing, one must say that the danger of infection is always lurking even with closed medullary nailing but that it can be greatly reduced by strict observance of the contra indications (see pages 8–10) The fatal outcome in the above cases was due exclusively to errors in the indication, in technique or in the after-treatment It is evident from these cases that all patients with skin pathology such as burns, severe contusions over the fracture, wounds in other parts of the body, marked swelling tension blebs and scarred skin must be excluded from medullary nailing Also children's fractures must not be nailed since in them fractures which would be suitable for medullary nailing heal well and rapidly without operation

Infection following Open Medullary Nailing

Häbler reported infection in 11% of cases following open medullary nailing while only 1.5% had infections following closed nailing

Küntscher s *open medullary nailing* exposes the patient to the same danger of infection as any other open osteosynthesis with exposure of the fracture field Infection, however, is very apt to become more dangerous with this than with any other method because the entire medullary cavity is exposed and might therefore become involved in the infection, whereas with other methods the inflammation of the bone marrow is confined to the fracture stumps The indications for open medullary nailing must therefore be made very carefully and must be very limited (see page 57) In the first edition of this book I wrote that the danger of infection has decreased slightly because the operation usually takes less time than with other methods and because immobilization is much more solid But these two advantages which are not always present are more than outweighed by the risk of a progressive infection in the entire medullary cavity

I further wrote If infection develops following medullary nailing, the course is the same as in any infected compound fracture and entirely different from that of genuine acute osteomyelitis Unfortunately however I have since had new experiences which showed that occasionally the same symptoms may develop as in genuine osteomyelitis (see page 147 and Figs 480–489) I was particularly shocked by the observation that even after many weeks and months following an initial uncomplicated course an acute osteomyelitis may develop suddenly in the midst of excellent health (see pages 272–276 and Figs 884–893 and 910–915)

skin showed bluish discoloration and marked tension Nailing was performed in spite of this On the sixth day fluctuation was present over the nailing site Upon removal of the sutures pure thick blood discharged. The temperature was normal On the 11th day the swelling of the leg had subsided considerably The operative wound showed no reaction An Unna bandage and a cast were applied and he started walking on crutches Pain, swelling and fever developed four days later After another 5 days a large abscess over the fracture site was incised. Three weeks later the entire lower leg was suppurating Because of his poor general condition, the leg was amputated Later a metastatic infection developed in the right ankle joint and an empyema of the pleural cavity Death from septicemia occurred 5 months later

In this case the fatal infection might have been due to the fact that he was not nailed until the second day when there was already marked swelling This caused a hematoma at the nailing site which had to be opened later From there the infection might have spread because he was permitted to get up too soon although the nailing site was still open

From this we must conclude that nailing should not be performed if marked swelling is present and that ambulation should not be started until the wound is completely healed

The following impressive observation was published by Stotz

Case F K. a 64-year-old man, had a fracture of the leg between the middle and distal third. The tibia was broken transversely with a 1 cm. fragment on the medial side At first wire extension was used through the heel reduction and plaster cast. Indications for operation Age cardiac insufficiency with asthma and chronic bronchitis bilateral malleolar fracture on the same leg, as well as instability of the fracture. Nine days after the injury nailing with 2 nails was performed easily (Aug 10 1941) A sugar-tong plaster splint was applied and the wound healed without complications Four weeks after nailing inflammatory redness and swelling developed at the nailing site but disappeared in a short time. Five weeks after nailing the patient was ambulant with a sugar tong molded splint which was still necessary at this time because of the bi malleolar fracture at the ankle, angulation of the tibia and outward rotation of the foot Soon thereafter an ulcer developed over the fracture site within an area of varicosities (bacteriological findings *Hemolytic staphylococcus*) through this ulcer a sequestrum of 1 cm. separated (Nov 17 1941) A few days later a small abscess formed at the nailing site which healed rapidly after incision On December 24 1941 i.e 11 weeks after nailing he was discharged with an Unna boot, able to walk satisfactorily Since the wound on the lower leg showed no tendency to heal, he was again institutionalized later On the day following curettage of the wound, the temperature rose and a cellulitis developed around the nailing site Through a broad incision a large amount of pus was removed The nail which was surrounded by pus was removed at the same time (Feb 3 1942) Thereafter he developed an empyema of the knee joint (bacteriological findings *Hemolytic streptococci*) and a peri-articular cellulitis developed which spread in spite of wide incisions Subsequently transient ileus developed aggravating the general condition which was already poor from the extensive suppuration On March 6 1942 he died

Post mortem examination Small ulcer over the lower half of the right lower leg on the medial side purulent cellulitis surrounding the knee joint and severe purulent sloughing inflammation of the lower colon. The medullary cavity of the tibia was filled with a grayish red and grayish white tissue. *Histologic findings.* The bone marrow of the tibia was transformed almost completely into cellular granulation tissue and young connective tissue, within which were a large number of

If infection occurs in a compound fracture, the bone marrow is involved in the process usually only for a few millimeters therefore only small superficial sequestra form (Fig 514) which are the greater the farther the periosteum has been destroyed The inflammation does not spread through the medullary cavity because it has been opened by the fracture and therefore no pressure can develop Large sequestra form only if the bone contains long fissures **Consequently, only a local osteitis develops in compound fractures and not an osteomyelitis if no medullary nail has been used**

If inflammation sets in after medullary nailing, it also involves the bone marrow Thus an osteomyelitis develops in contrast to the local osteitis which follows the infection of a fracture which has not been nailed In the beginning, however, this process takes a different course from the genuine acute osteomyelitis because the cavity is wide open at the fracture site and because an additional opening was made at the nailing site For this reason the pressure does not assume, in the beginning such a dangerous proportion as in the common acute osteomyelitis and the inflammation takes therefore a less dangerous course if the wound is immediately opened The medullary nail, by its shape, acts like a draining tube The inflammation in the medullary cavity is usually confined to the surroundings of the medullary nail and does not involve the entire marrow as in a phlegmonous inflammation of acute closed osteomyelitis The only exception which I have seen to date is the case discussed on pages 147–150 in which a process developed which was indistinguishable from acute osteomyelitis since a new inflammation developed one year after closure of the wound when bony union between the fragments had again converted the medullary cavity into a closed space

The inflammation of the soft tissues takes the same course in acute osteomyelitis, in compound fractures and in medullary nailing If the pressure is not released in time by removal of the sutures or by adequate incisions, the inflammation progresses along loose tissue spaces (see pages I/141–146 and Figs 120–122 E, I/182–184)

The *processes occurring in the bones* in virulent wound inflammations are pictured in Figs 490–526 and 1140–1143, and the low grade processes in Figs 213–221, 649–656 671–678 856–863 864–873 and 894–901 Sequestra of the tibia, of the size pictured in Figs 511–513 and 519–522 have been observed only after medullary nailing of pseudarthrosis in which the periosteum had been stripped for some distance never after medullary nailing of fresh compound fractures Since there is no pressure inside the bone with medullary nailing as long as the fracture has not united periosteal appositions extending over the entire bone as in common osteomyelitis do not occur Such extensive appositions can appear only from a flare up after the fracture has healed as shown in Figs. 484–489 I have noticed the separation of massive sequestra only after nailing of forearm fractures (Figs 1140–1143) As a rule these sequestra do not resemble crown sequestra as they occur in non nailed infected fractures and in amputation stumps from which the marrow has not been curetted These form a ring or part of a ring and consist chiefly of the outer layers of the cortex They form a more or less flat funnel shaped stump (Figs 509 510)

If an inflammation develops, we must distinguish between an infection of the bone marrow, of the bone, and of the soft tissues. The essential feature of any inflammation is tension As soon as this tension is relieved either by incision or by spontaneous opening, the symptoms, pain, swelling, redness and heat disappear This can best be observed in a subcutaneous abscess of the tip of the finger The throbbing pain due to the pressure within the tissues causing sleepless nights disappears immediately upon incision of the inflamed area and thorough removal of the dead tissue under good anesthesia, using a tourniquet If the finger is then immobilized on a properly bent wire splint and if the bandage is not removed for 10–14 days one will find the incision healed and completely epithelialized in most cases The germs disappear spontaneously without the use of a chemical agent, serum or of irradiation *(see pages I/140, I/752)*

If the pressure is not released in time, the pain will cause serious local disturbances of the circulation in the minute vessels within the inflamed area under pressure If the blood does not circulate, the tissues die rapidly and if the involved area is too large to be removed one must wait until it separates spontaneously The suppuration will last until this process of sloughing is completed and if pus retention causes renewed pressure, the patient s temperature will again rise

Acute osteomyelitis is the classic example of extreme pressure because the inflammation of the marrow takes place in a completely closed and absolutely unyielding cavity within the bone Because of the rigidity of the wall, extreme degrees of pressure develop within a few hours The pain is excruciating and a stasis develops in the blood vessels of the marrow Because of the lack of circulation, the bone marrow and large parts of the bone become necrotic and are then sequestrated by an extremely prolonged disease process unless they are removed immediately Necrosis of the affected part of the bone occurs within a few hours so that serious damage results even if the pressure is released on the second day of the disease by drilling or fenestration The tremendous irritation stimulates the periosteum to marked activity and a large involucrum forms since usually young people are affected. In an adult if a localized osteitis develops in the wake of a compound fracture or if an osteomyelitis develops after medullary nailing, the periosteal appositions are much less marked because the periosteum is thinner and does not react as vigorously

That serious damage may result from pressure even without primary infection can be seen in mechanical obstruction of the intestines or the bladder The pressure stimulates centripetal nerve endings and this is felt as severe pain. Pain in turn causes circulatory disturbances leading to necroses in the wall of the intestines or the bladder To this is added the toxic effect of the bacteria and of the products of decomposition

Another example of extreme pressure is gas gangrene marked by severe ischemic pain local interference with the circulation with corresponding discoloration of the skin and toxemia The circulatory disturbance is caused partly by mechanical pressure, partly by vascular spasms which are probably caused by toxins.



Fig. 494 Fig. 495
August 26, 1942

Fig. 496 Fig. 497
November 2 1942

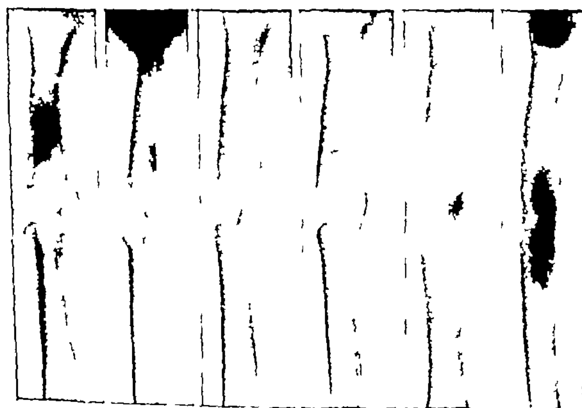


Fig. 498 Fig. 499
November 6 1942

Fig. 500 Fig. 501
June 2, 1943

Fig. 502 Fig. 503
May 30, 1944



Fig. 490 Fig. 491 Fig. 492 Fig. 493

July 7 1942 July 7 1942

Figs. 490, 491 Compound leverage fracture of the right femur with marked lateral displacement, shortening and angulation in a 16-year-old girl who fell out of a cherry tree onto a pile of manure. Admitted 12 hours later The proximal fragment protruded 8 cm. through the wound, was denuded of periosteum and soiled with manure Observation of Ehalt.

Figs. 492 493 Same as Figs 490 and 491 After painstaking excision of the muscles and debridement of the bone under local anesthesia a medullary nail was inserted and the wounds were drained with a thick rubber tube Tetanus antitoxin but no gas gangrene serum was administered. Sulfathiazole was dusted into the wound. Placed on a Braun leg frame.

Figs. 494, 495 Same as Figs. 490–493 after 7 weeks. A violent inflammation ensued which quickly subsided after removal of the sutures. The distal end of the proximal fragment developed a massive sequestrum in the lower part and a medullary sequestrum in the upper part. Fuzzy periosteal callus formation as in Figs. 295–298.

Figs. 496 497 Same as Figs 490–493 after 13 weeks. The involucrum has become stronger on the medial and posterior aspects.

Figs. 498 499 Same as Figs 496 and 497 4 months after injury and 4 days after removal of the medullary nail and the sequestra The cavity is clean. The bone has bent slightly because the involucrum was still too weak. Varus angulation of 10°

Figs. 500, 501 Same as Figs. 490–493 after 11 months. The wounds closed 5 weeks after removal of the nail and the sequestra. The bone has become strong All joints are freely movable. No shortening Varus angulation of 10°

Figs. 502, 503 Same as Figs 500 and 501 after 1 year and 2 years after the injury The bone defect has completely filled. No discomfort at any time.

Sequestra following medullary nailing however are located inside the bone and are cone shaped, 1 to 4 cm in height. In contrast to crown sequestra, they consist chiefly or entirely of those parts of the cortex which adjoin the medullary cavity (Figs. 219, 511–513) If the periosteum has been stripped for some distance by the



Figs. 511–513

Figs. 511–513 Two purely medullary sequestra following infection in a nailed tibia, showing no involvement of the cortex (see Figs. 519–522)



Fig. 514

Fig. 514 Sequestra from infected gunshot fractures of the lower leg From broadly exposed fracture ends, only small filigree like superficial pieces of the cortex separate as a rule Large sequestra as pictured on the right are wedge fragments or fragments which had already been loosened by the trauma.

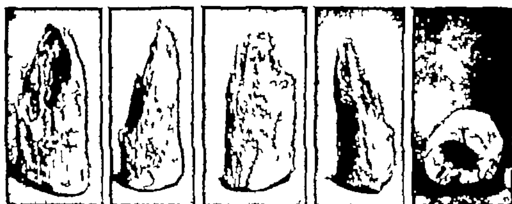
and posterior sides (Figs. 494–497 and X ray picture of A. W Fischer and Reich) which become so strong after removal of a sequestrum that the bone unites with negligible shortening No observations are available as to whether a similar favorable course may take place in adults after the separation of such a large sequestrum In adults the periosteal appositions following massive sequestra are not sufficient to rebuild the bone because the periosteum is not endowed with such regenerative power (Figs. 1136–1151)

On the tibia periosteal appositions are comparatively slight and a large gap develops in the bone which can be bridged only by shortening the leg through an osteotomy of the fibula. Fortunately such gaps are rarely as large as those shown in Figs 523–524 No experiences are available on the reaction of the tibia in juveniles in this respect.

From the foregoing it is evident that the inflammation after medullary nailing does not always take as mild a course as had often been reported previously, but may become very malignant and lead to loss of limb or life Since we never know whether an initially favorable case may develop a late osteomyelitis after months (Figs. 884–893) or years (as in the case described on pages 147–150 and illustrated in Figs 480–489) we must be particularly cautious in determining the indications for open medullary nailing

We have seen complications in the wake of infected nailed fractures such as were entirely unknown with *any other methods* Such bone destruction as shown in Figs 490–526 864–873 and 1136–1151 is seen only in the wake of medullary nailing

A. W Fischer and Reich have published three cases of infection following medul



Figs. 504–508

Figs. 504–508. Photographs of the combined massive and medullary sequestrum of Figs 494–497 which was removed on November 2, 1942 Postero-laterally the full thickness of the bone sequestrated towards the tip only the parts adjoining the medullary canal



Figs. 509 510

Figs. 509 510 Typical crown sequestra from an infected amputation stump of the femur It is evident that only the external cortical parts of the bone have separated and not the parts adjoining the medullary cavity

accident or by an operation part of the external layer of the bone may become necrotic as well (Figs 504–508) Such large medullary sequestra as shown in Figs. 490–526 are much less common than smaller ones which comprise only the inner layers of the bone (Figs 219 869) In rare cases one can find several small central sequestra (Figs. 219 869) at some distance from a typical medullary sequestrum. These peculiarly formed sequestra at the fracture ends come about by mechanical destruction of the bone marrow and by further absorption of the surrounding tissues through the inflammation. The sequestrum in the proximal fragment is usually much larger than in the distal fragment because the marrow is first destroyed by the guide pin and later pushed out as the medullary nail is driven in The marrow of the distal fragment suffers much less damage If the marrow is destroyed at the fracture site mechanically as well as by inflammation the blood vessels in it are destroyed and therefore the inner layers of the bony tube must become necrotic and must be eliminated If an additional destruction of the periosteum causes lack of blood supply from the outside large sequestra form as shown in Figs 504–508 I call these peculiar cone-shaped sequestra because of their genesis and their location, *medullary sequestra*

In juvenile femora marked periosteal appositions develop chiefly on the inner



Figs. 521 522. Same as Figs 515–518, after removal of the nail. The remaining walls of the bone are still thin

Fig 523 Same as Fig 521 6 weeks after removal of the sequestrum (Figs. 511–513) There is still a wide gap between the bones.

Fig. 524. Same as Fig 521 8 weeks after the second osteotomy of the fibula. The gap between the tibial fragments begins to close.

Figs. 525 526. Same as Fig 523 20 months after removal of the medullary sequestra, and 1 month after the third osteotomy of the fibula. A bridge is beginning to form over the gap Large callus clouds on the anterior surface of the tibia. The calcium content has increased. If in this patient merely an osteotomy of the fibula had been performed on November 24, 1942, and the tibia straightened without exposing the fragments, it would probably have united firmly in good position in 6–8 weeks. A plaster cast would have been needed after the operation for only 2 months instead of for 2 years, the joints would not have stiffened and the leg would not be 3 cm. shorter

seen with more or less diffuse perivascular small-cell infiltrations small hemorrhages and marked hyperemia Adjoining this is a wide zone of entirely normal cortical bone and periosteum without signs of osteitis or periostitis No extension of the inflammation through the Haversian canals and no abscesses were found

The *leg fracture* showed the following

After removal of all soft tissues the specimen showed nothing unusual macroscopically except for the fracture site described later The periosteal tube was smoothly attached to the tibia with no evidence of elevations or abscesses

The fracture is bridged merely by fibrous tissue. In cutting this with a knife the tissue crunches which is evidently due to calcified areas or remnants of bone. A longitudinal saw cut through the entire bone showed the condition of the cortex and of the cancellous regions (ankle) above and below the fracture to be entirely normal to external inspection This section shows plainly that the cortex is lined on the inside by an obviously dense fibrous tissue of 3 to 5 mm in thickness Contiguous to this we found rather soft marrow above as well as below the fracture which was obviously suppurating in the center where the nail had lain. These conditions prevailed equally all over

"On transverse sections a central cavity still 2 mm in diameter was plainly not ceable through the entire length of the bone marrow At the fracture stumps the marrow is lacking and inter

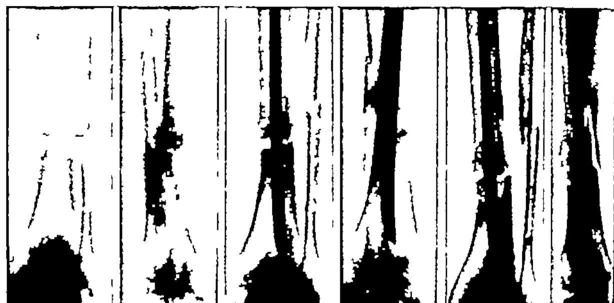


Fig 515 Fig. 516 Fig. 517 Fig. 518 Fig. 519 Fig. 520
November 24 1942 November 24 1942 February 24 1943

Figs. 515 516. A 5-months-old fracture of the left tibia with delayed callus formation in a 28-year-old woodsman who fell off a motor-cycle. Was first given a padded cast for 2 weeks, then wire traction through the os calcis with 7 Kg for 15 days. The fragments were distracted 8 mm. Another cast was applied. The callus cloud is visible medially The tibia is loose

Figs. 517 518. Same as Figs. 515 and 516. After oblique osteotomy of the fibula, transverse freshening of the tibia and medullary nailing, performed *elsewhere*. The fragment gaped medially and anteriorly

Figs. 519 520 Same as Figs. 515–518, after 3 months. High fever immediately after operation, which subsided in a few days after removal of the sutures. A large medullary sequestrum is separating from the proximal fragment, a small medullary sequestrum from the distal fragment (Figs. 511–513)

lary nailing Their pictures of sequestra are entirely similar to those of Figs 490–526 In one femur and in one leg, amputation was necessary They examined the specimens thus obtained macroscopically and microscopically reporting as follows

"In the *femur fracture* the following areas were examined microscopically

1 Parts of the original fracture site with marrow and nail bed

"2 Transverse section of the femur above the fracture.

"The specimens were decalcified and stained with H E according to van Gieson and with Sudan

At the site of the original fracture (nail bed) fibrin and a small seam of non-specific inflammatory granulation tissue were found sharply set off against narrow and wide-meshed hyperemic medullary tissue with perivascular round-cell infiltration. In the reticulum, the cells of which had a large cell body and small intensely stained nuclei were large cells, evidently fat-storing histiocytes Adjoining was a zone of freshly formed bone trabeculae with distinct osteoblastic seams. The medullary tissue shows edema, marked hyperemia relatively many scattered round cell elements and large histiocytes Polynuclear elements were few in number

"On the cross section of the femur above the fracture a narrow strip consisting of blood and masses of fibrin mixed with inflammatory cells can be seen in the nail bed The structure of the marrow is lost Adjoining this but fairly sharply delineated is seen a non specific inflammatory granulation tissue with peripherally increasing connective tissue organization. This again merges into loose granulation tissue Finally narrow and wide meshed medullary tissue (fat islands) are

Treatment of Infections following Medullary Nailing

If infection occurs following *closed* medullary nailing redness, swelling and pain usually appear first at the nailing site later sometimes at the fracture site Since pressure is the essential feature of all inflammation, it must be relieved In closed medullary nailing this is best done by removing the sutures at the nailing site Blood mixed with fat droplets under pressure will then discharge from the wound The temperature will then drop, the pain subside and the wound closes Sometimes pus forms locally but ordinarily this soon disappears A spread of the infection as described on page 150 will as a rule follow only errors in indication and technique

After *open* medullary nailing the inflammation usually takes a more serious course and the sutures at the site of injury must be removed as well, and sometimes incisions for the drainage of the pus have to be made The nail must not be removed because it is the best means of immobilization and therefore, after decompression, the best means for combating the inflammation In femur fractures it must remain in situ until the periosteal bridges of callus are strong enough to prevent subsequent angulation (Figs 498 499) Sequestra are removed together with the nail On the lower leg the nail should remain about two months until the sequestra have become detached If union is not firm, a cast is applied Under no condition should traction be used because this would increase the gap between the fragments If the hiatus on the tibia is wide (Figs 523, 524) the fibula must be osteotomized in time so that the fragments can approximate

Frequently the unhealthy condition of the skin does not permit the use of bone grafts for bridging the defect If the inflammation should progress in spite of extensive incisions, timely amputation must not be omitted

mediate fibrous tissue is interspersed. Macroscopically it cannot be decided whether any ossification has taken place. It is striking that the entire cortex presents an absolutely normal impression to inspection except the area involved in the fracture. The cancellous bone in the ankle region shows likewise no abnormalities and no sequestra. Fine trabecular structure is seen everywhere, no increased porosity or sequestration.

"The conditions of the soft tissues do not require further comment for the purpose of this discussion

"Microscopic examination This was applied to the fracture and to several levels at about 10 cm distance from the fracture upwards all in transverse sections The specimens were treated as above

"Microscopic findings at the fracture site In the central portions of the bone marrow the normal medullary tissue was replaced by a tissue containing predominantly round-cell and some polynuclear inflammatory elements also masses of fibrin and numerous thin walled vessels partly dilated and gorged with blood. This picture prevailed in areas immediately adjoining the nail. It is striking that in these areas the inflammatory elements condensated to pus foci of only small size This tissue, which represents granulation tissue containing numerous inflammatory elements, merges into a typical granulation tissue containing numerous fat-storing histiocytes more so as one approaches the periphery of the medullary cavity

"This rather loose granulation tissue in turn merges into a connective tissue area becoming denser and denser and containing inflammatory elements in the form of perivascular predominantly round-cell infiltrations Here the vessels are thick walled. Quantitatively the inflammatory infiltration decreases distinctly The picture is that of inflamed central medullary portions being surrounded by a connective tissue sheath of peripherally increasing density in which large hyaline areas are present. On the outer surface of this sheath fresh bone formation, representing myelogenous callus can be seen in rather even distribution up to the fracture site. The newly formed bone trabeculae show normal structure. This represents endosteal medullary callus and intermediary callus Adjoining this zone of ossification lies the cortex of the tibia with a perfectly normal structure and no pathologic changes whatsoever In the immediate proximity of the fracture, the Haversian canals are dilated and contain a fine meshed framework with fibrin and blood vessels in addition to round-cell elements in perivascular arrangement. In some dilated Haversian canals more or less distinct new bone formation is evident

"Sharply offset against this cortical zone is a wide zone of periosteal bone appositions which in turn is covered by dense connective tissue. This represents periosteal callus.

"Microscopic findings at a distance from the fracture The transverse section shows essentially the same picture with the exception of the absence of periosteal new bone formation and a more distinct outline of the various structural strata. The most centrally located areas of the marrow are converted into inflammatory granulation tissue which becomes looser toward the periphery and merges into a dense connective tissue sheath in which the inflammatory cellular elements diminish more and more On the outside of this sheath there is endosteal new bone formation with well-formed trabeculae even at this distance from the fracture. Adjoining this there is again the wide *cortical zone and the periosteum both showing nothing worthy of note.*

"In summary we find a picture of suppuration of the central parts of the bone marrow limited to the former nail bed Even within the peripheral medullary areas a demarcation of the inflammation by a sheath of dense fibrous tissue took place. Only in the fracture area does the marrow still show considerable inflammatory infiltration. No abscesses proper were found anywhere and in no way did the picture indicate a phlegmonous inflammation with total disintegration of the bone marrow Cortex and periosteum are not involved in the inflammation. Lively new bone formation in the form of periosteal appositions is found in the fracture area. Here also absorption occurred but production predominated Intermediary and medullary callus had formed The latter formed also at a distance from the fracture at the periphery of the marrow



Fig 527

Fig 527 Thigh secured in screw traction apparatus for nailing Patient in lateral recumbency on well side slightly flexed forward to make the greater trochanter more accessible The well leg is acutely flexed at the hip In fractures close to the knee joint the knee is also flexed to a right angle and the calf fastened to the foot plate. A wire through the femur may be used for traction. The nailing site is marked with a cross. The thigh is secured medially and laterally by loops attached to the crossbars. Two additional straps can be used for securing the thigh in an antero-posterior plane. A strong easily regulated traction can be exerted by the windlass principle.

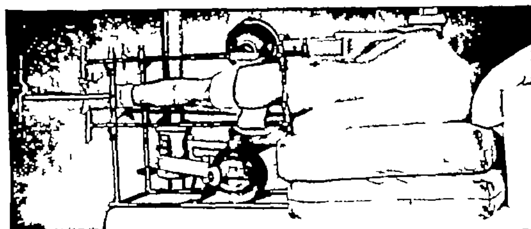


Fig. 528

Fig. 528 Position as in Fig 527 The fragments are secured in antero-posterior direction by straps attached to the rotating double bars of Linsmayer The two X ray tubes are in position for fluoroscopy or radiography In fractures close to the knee joint the knee is flexed to a right angle.

may be fatal If the patient is in a poor general condition only a pin or wire extension may be used (see page 8)

Contra indications with regard to the bone All fractures less than 7 cm removed from the tip of the trochanter or from the kneejoint are not suited for nailing neither are some spiral fractures with a long butterfly fragment (Figs 161–168 582–587) nor fractures in bone diseases if the medullary canal is blocked, as in some cases of Paget s disease

Tabes is no contra indication

SPECIAL PART

FRACTURES OF THE FEMUR

Closed Medullary Nailing of Femoral Fractures

General prerequisites with regard to the patient Medullary nailing must not be carried out unless the patient is in good general condition Therefore the heart, lungs, kidneys, reflexes, the mobility of the joints and the sensation must be examined carefully The skin must be in good condition and must show no injury or inflammation even in other parts of the body removed from the fracture. No inflammatory processes should exist in other organs (e g , tonsillitis)

Local prerequisites with regard to the patient All *closed transverse fractures* in the middle third of the femur (Figs. 108–115) i e , in the region of the isthmus of the medullary canal, are particularly suited for nailing However, all transverse fractures in the proximal and distal third of the femur are also suited if they are at least 7 cm removed from the tip of the trochanter or from the kneejoint In short or even in longer oblique fractures in the region of the isthmus or above the nail gives satisfactory fixation (Figs 540–547) In oblique fractures in the lower third, very accurate apposition of the fragments and deep anchorage of the nail in the cancellous bone of the distal diaphysis are essential for success (Figs 416–423)

Fragmented and comminuted fractures require supplementary continuous traction (Figs 574–581, 618–638, 649–656)

Spiral fractures with a long butterfly fragment are not suited (Figs. 582–589)

Old fractures of the femur which formed no callus because of excessive traction as in Figs 301 302 can be successfully treated by closed nailing, even after the lapse of months.

Some *refractures of the femur* are suited to nailing

Aseptic *gunshot fractures of the femur* can be treated with closed nailing after 2 to 3 weeks if all the wounds are healed (see page 212)

Perhaps *fresh gunshot fractures of the femur* with large wounds could be nailed if the wounds are left wide open (see page 208) and secondary closure performed later

Contra indications with regard to the patient If the general condition is poor (weak, rapid pulse pale appearance cold sweat) medullary nailing must not be performed under any circumstances, because it is not an urgent operation. If **the patient is in profound shock as is frequently the case in multiple injuries, medullary nailing must absolutely be omitted because the result**



Fig. 530

Fig 530. Fracture of the femur secured in the apparatus of Wittmoser Posterior view

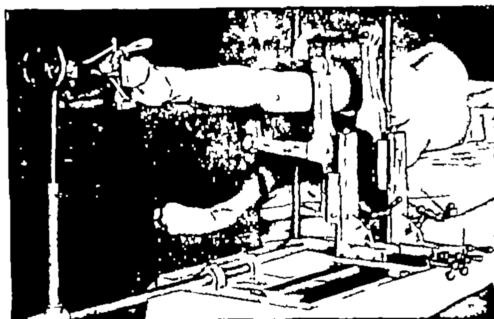


Fig. 531

Fig. 531 Same oblique view from behind and below illustrates the action of the reducing rings. In fractures close to the knee, the knee joint is flexed to a right angle.

penetrate into the knee joint and cause serious damage Thus far, most complications have arisen from the use of nails that were too short (Figs 161–168, 222–229, 234–243 390–399 400–407 582–589, 641–646 671–678) The most serious complications however follow the use of a nail that is too thick, because it becomes jammed in the medullary canal and then can neither be driven in further nor extracted (pages 56 79) The width of the canal is measured on the X ray pictures The isthmus is located slightly above the middle (Figs 1–9) In adults it varies between 8 to 12 mm but may run as high as 16 mm If the X ray pictures have been taken with a focus-film distance of 80 cm 1 to 2 mm must be deducted from the width indicated by the X ray pictures If the bone shows a marked curve, the next thinner nail must be used. If too thick a nail is selected difficulties will be encountered during the operation because it cannot be driven in far enough (Figs

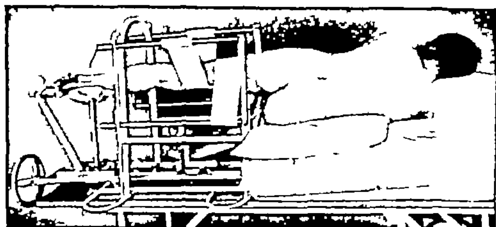


Fig. 529

Fig 529 Femur fracture secured in the reduction apparatus of Linsmayer In fractures close to the knee joint the knee is bent to a right angle.

Requirements on the part of the surgeon He must be experienced in bone surgery and must have the apparatus and instruments listed on pages 22–26 at his disposal.

Local anesthesia and X ray technique Satisfactory X ray pictures of sufficient size and taken in both planes are an absolute prerequisite for medullary nailing They can be taken only if the fracture is first anesthetized locally (see page I/99) For a satisfactory survey and exact measurements of the medullary canal and in order to avoid a possible overlooking of additional injuries the X ray pictures should be at least 40 cm. long If the fracture is distal from the middle, pictures of the proximal half must also be made to visualize possible changes in this section of the bone and its curve

Time of operation If the general condition is satisfactory, the operation may be performed on the first day The fragments can best be reduced during the first hours before the hematoma and the swelling become large. If the operation cannot, for some reason, be performed within the first few hours it may be performed within the next few days provided the swelling is only slight otherwise, one must wait until the swelling has subsided completely i.e , one week or longer If wounds are present on the fractured leg or on other parts of the body and the operation cannot be performed immediately one must wait until these wounds have entirely healed, i e. two to three weeks otherwise they may break open become inflamed, and cause a metastatic infection of the nailed fracture

Determination of the length width and curve of the medullary canal After the X ray pictures have been completed and after the time has been set for the operation the length of the sound femur is measured in lateral recumbency with the hip and knee joints flexed at a right angle from the tip of the trochanter to the knee joint This measurement determines the length of the nail required. If it is permitted to protrude 2 cm. beyond the tip of the trochanter it will reach distally into the region of the epiphyseal line (Figs 695 696) Only in fractures above the middle may it be somewhat shorter It must however not be too long for then it will

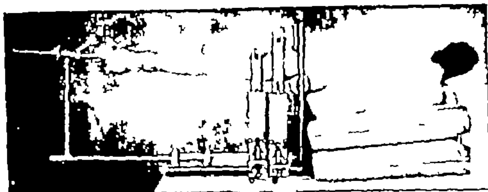


Fig 530

Fig 530 Fracture of the femur secured in the apparatus of Wittmoser Posterior view

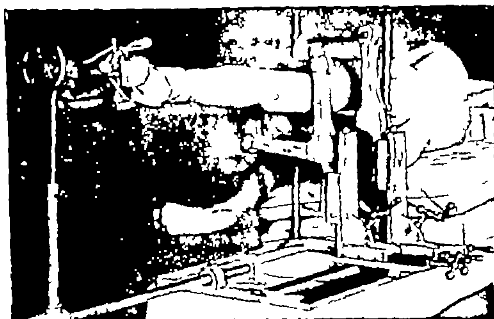


Fig. 531

Fig 531 Same, oblique view from behind and below illustrates the action of the reducing rings. In frac tures close to the knee, the knee joint is flexed to a right angle.

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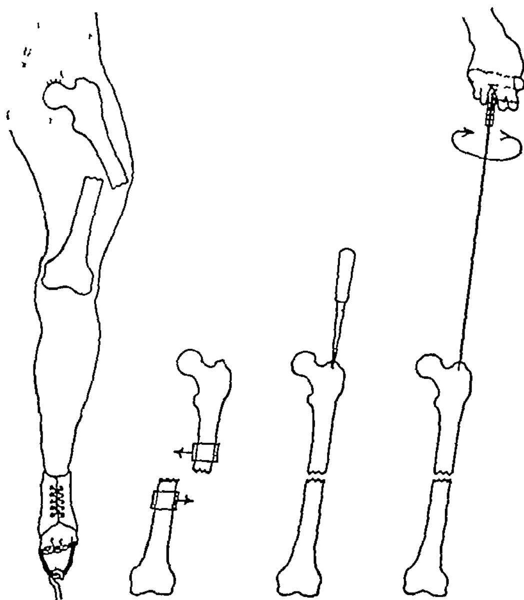


Fig. 531 a–d

Fig. 531 a. Transverse fracture of the femour at the middle with varus angulation lateral displacement and shortening, placed under longitudinal traction (Figs. 527–531)

Fig. 531 b. After correction of the angulation and the shortening the lateral displacement is corrected by traction straps (Figs. 527–529) or by the wooden rings (Fig 530)

Fig 531 c. *After exact reposition the greater trochanter is pierced with the awl (Fig. 73) through a 2 cm. skin incision 5 cm. above the trochanter*

Fig 531 d. The guide pin by means of the handle (Figs 81 82) is inserted through the hole made by the awl.

194–197) If it is too thin and too short angulation (Figs. 400–407) and rotation (Figs. 222–229) may develop later or a new fracture of the bone may even occur (see page 87)

The instruments and apparatus listed on pages 22–26 must be in readiness

Personnel The staff necessary includes an assistant to supervise the condition of the patient (appearance pulse) and the anesthesia a fluoroscopist a scrub nurse, and an X ray technician

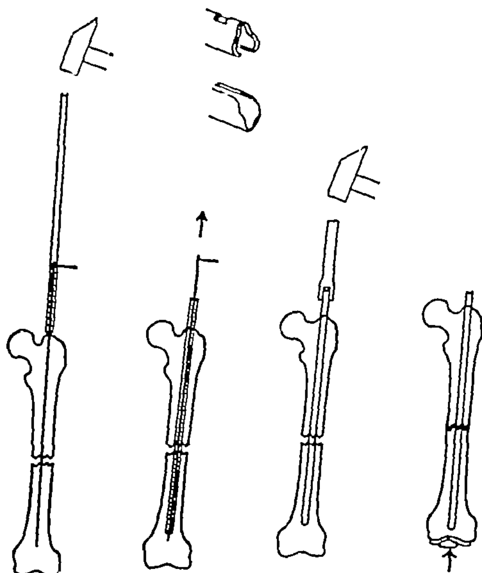


Fig. 531 e–h

Fig. 531 e. If the X-ray pictures show good position of the guide pin, the medullary nail (Fig. 67) is driven in over it.

Fig. 531 f. When the head of the nail comes near the skin incision the guide pin is pulled out.

Fig. 531 g. For the further driving of the medullary nail, the punch with a 2 cm. bore (Fig. 75) is used

Fig. 531 h. After the nail has been driven in far enough, i.e. until it protrudes only 2 cm. beyond the trochanter the fragments are impacted.

Anesthesia If the nailing is done immediately the local anesthesia given for the X ray pictures is sufficient For the introduction of the guide pin, the trochanter region is infiltrated and for the driving of the nail, a short general anesthesia can be given if necessary If the general condition is good, spinal anesthesia is very well suited If spinal anesthesia is used no narcotic preliminary medication should be given, for this may cause a dangerous drop in blood pressure, if the spinal anesthesia should fail and a general anesthesia thus become necessary, or if the procedure becomes prolonged which can never be foreseen

Protection against heat loss during the operation For this we provide the patient especially if the procedure is prolonged with a wool jacket and with a warm long stocking and trouser for the sound leg, as well as for the lower leg of the injured side

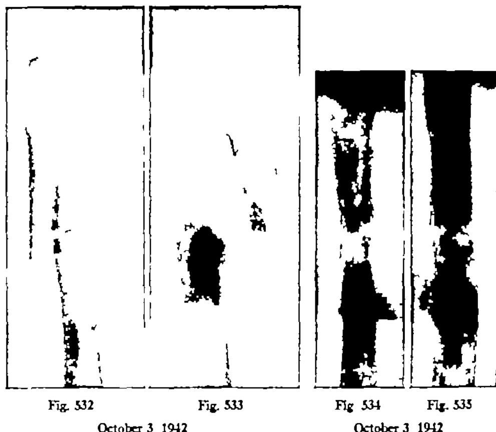


Fig. 532 Fig. 533 Fig. 534 Fig. 535

October 3 1942 October 3 1942

Figs. 532, 533 Transverse sheared fracture of the femur between middle and upper third in a 17 year-old roofer who was knocked off his bicycle by a truck. The distal fragment is displaced medially by the full width of the shaft and posteriorly by more than twice the thickness of the shaft.

Figs. 534 535 Same as Figs. 532 and 533 after correction of shortening by traction and of the lateral displacements by transverse pressure and pull in Wittmoser's apparatus. The shadows of the wooden rings are visible Lengthening of 7 mm.

Application of the foot hitch The foot is padded and the foot hitch applied (Figs 527–531)

Position of the patient on the reduction apparatus Lateral recumbency as recommended by Küntscher has proven to be the most advantageous position The patient lies on the well side with marked flexion of the well hip and slight flexion of the injured leg In this position the tip of the greater trochanter becomes most readily accessible (Figs 527–531) The fractured leg with the knee extended is placed upon the reduction apparatus and the foot is fastened to the footplate in such a way that it cannot rotate In fractures of the distal third of the femur, we have lately flexed the knee to a right angle and fastened the leg below the knee to the footplate or used wire traction through the femur

Setting up the X ray machines The original X ray pictures not sketches, are displayed for convenient inspection and measuring during the operation, a leg skeleton is at hand and one X ray tube is placed opposite the extensor side and the other under the medial side of the thigh as in Fig 528

Reduction of the Fracture If the patient is lying strictly on his side and the

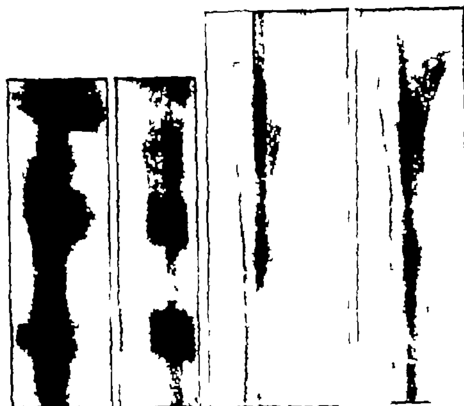


Fig. 536 Fig. 537 Fig. 538 Fig. 539

October 3 1942 October 3 1942

Figs. 536 537 Same as Figs. 532–535 after nailing The fragments are still separated by 5 mm.

Figs. 538, 539 Same as Figs 532–535 after impaction of fragments which are now in accurate apposition. Got up after 4 days, left the hospital after 20 days, resumed previous work after 8 weeks. Compare with Figs 108–120.

leg is placed upon the reduction apparatus under slight traction in such a way that the medial border of the foot or with a flexed knee the medial border of the lower leg is in a horizontal plane the rotatory displacement between the fragments is eliminated By turning the screw the shortening is eliminated and by the lateral traction straps the lateral displacement and angulation are corrected In transverse fractures the lateral displacement can be overcome easily if the fragments are slightly distracted and a slight lengthening is produced (Figs 534 535) If only an ordinary screw traction apparatus is available the fragments are secured by loops of bandages which are tied after reduction (Fig 527) If the reduction apparatus of Linsmayer (Fig 529) or of Böhler (Fig 528) is at hand the traction straps are applied in that plane in which the lateral displacement and the angulation are more difficult to correct, which is usually the sagittal plane (Fig 528) By raising or lowering the rods and by alternate turning of two horizontal or two vertical rods displacements in the frontal plane can be corrected as well One may also fasten a strap to each of the four rods and thus exert traction in four directions Reduction can most conveniently be accomplished with the two wooden rings of the Wittmoser reduction apparatus (Figs 530 531) The reduction is performed under the continuous control of momentary fluoroscopic exposures with the two X ray machines Sometimes

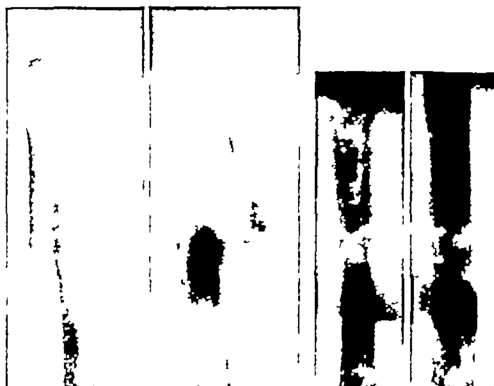


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October 3 1942 October 3 1942

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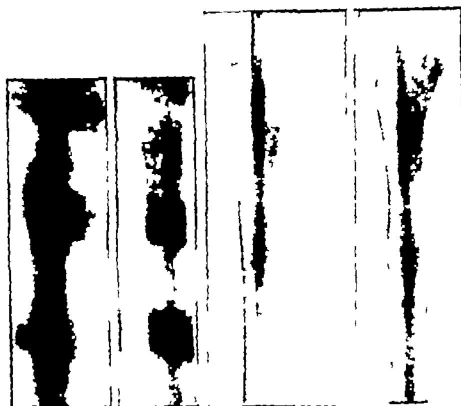


Fig. 536 Fig. 537
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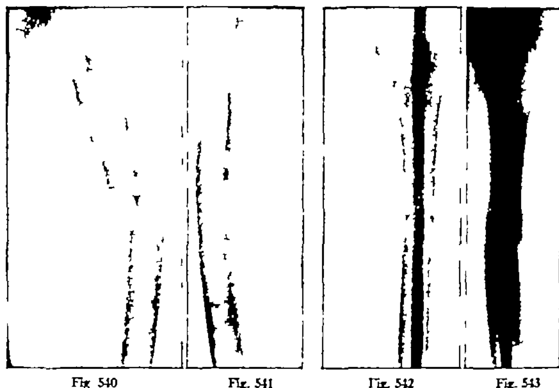


Fig 540 Fig. 541 Fig. 542 Fig. 543

September 18 1941 September 18 1941

Figs. 540 541 Spiral fracture of the left femur between middle and upper third in a 14-year-old boy who was knocked off his bicycle by an automobile.

Figs. 542, 543 Same as Figs. 540 and 541 after nailing under local anesthesia and short ethyl-chloride analgesia Excellent position of the fragments. Got up on the 10th day and left the hospital on the 18th day

it can be accomplished in a few minutes but it may consume one half or even one whole hour

In order to prevent *radiation injuries*, the rules given on page 37 must be carefully observed (use of lead gloves lead aprons and short exposures of 1–2 seconds) If the procedure is carried out in a darkened room the fluoroscopic screens are attached to the reducing apparatus (Figs. 102 103) so that they do not have to be held by hand.

X ray pictures If fluoroscopy reveals exact apposition biplane X ray pictures must be taken to insure the absence of angulation as in Figs 185–189 390 391 To shorten the waiting period a rapid developer is used (see page 35)

The operation must not be started until the fragments are reduced exactly because **good position of the fragments is the fundamental prerequisite for perfect healing**

Sterile draping of the operative field The operator does not scrub until after perfect reduction has been obtained The skin is then sterilized in the trochanter region and draped with sterile sheets leaving the thigh free in order that the direction in which the guide pin must be inserted may be clearly seen

Checking the guide pin The length and thickness of the guide pin are again checked to see whether it matches the medullary nail and the handle It must not

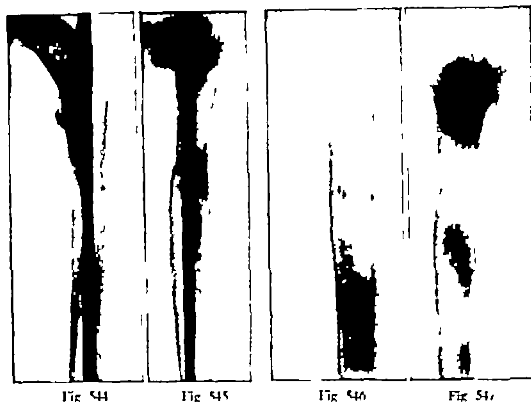
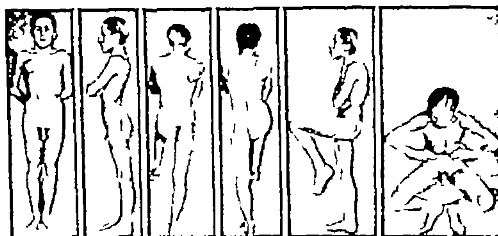


Fig 544 Fig 545 Fig 546 Fig 547

October 29 1941 September 14 1942

Figs 544 545 Same as Figs 540-543 after 6 weeks. Good but not excessive callus formation

Figs. 546, 547 Same as Figs 540-543 one year after injury and 6 months after extraction of the nail Fracture site thickened bone well consolidated. No shortening nor angulation Resumed work 10 weeks after the accident



Figs. 548–553

November 18, 1941

Figs. 548–553 Same as Figs 540–547 8 weeks after injury The left hip is slightly restricted because the nail protrudes too far All other joints are free. Muscles are strong

be too thin otherwise it may become jammed (see page 78), or the nail may slip off it It must not be too thick for a thin nail cannot then be driven in over it It must not be too short for then it will not reach into the distal fragment if the fracture is close to the knee joint

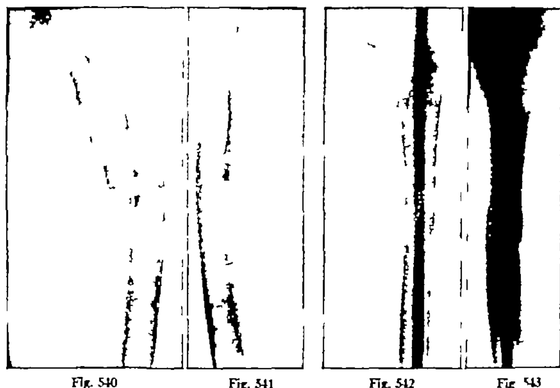


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September 18 1941 September 18, 1941

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Fig. 562 Fig. 563 Fig. 564 Fig. 565

August 6 1942 August 25 1942

Figs 562, 563 Fracture of left femur below greater trochanter and through the middle of the minor trochanter with unusually marked lateral displacement and shortening of 5 cm. The 40-year-old iron worker was knocked from his bicycle by a truck. Suffered also cerebral concussion and 2 contused lacerations on the head each 20 cm. long

Figs. 564 565 Same as Figs 562 and 563 immediately after medullary nailing which, because of the shock, was not performed until 19 days later in the open wound. The nail is inserted medial from the greater trochanter To prevent redisplacement, pin traction of 5 Kg was used for 6 weeks





Fig. 566 Fig. 567 Fig. 568 Fig. 569

October 2 1942 December 16 1942

Figs. 566, 567 Same as Figs 564 and 565 after 2 months. Good position good callus.

Figs 568 569 Same as Figs 562 and 563 after extraction of the nail 4 months after injury Bony union in good position No shortening no coxa vara. Ossification at insertion of ileopsoas muscle.

of the bone In fractures of the proximal third of the femur, the guide pin and the nail must be inserted medial to the greater trochanter otherwise a coxa vara (Figs

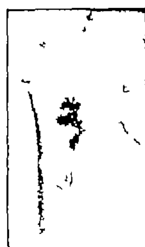








Fig. 554 Fig. 555 Fig. 556 Fig 557

August 20 1941 August 20, 1941

Figs 554 555 Fracture of the right femur below the greater and above the minor trochanters. Distal fragment displaced backwards by full shaft's thickness. Coxa vara. The 30-year-old painter fell 5 m. from a scaffold.

Figs. 556, 557 Same as Figs 554 and 555 after reduction in screw traction apparatus and insertion of guide pin.









Fig 558 Fig. 559 Fig. 560 Fig. 561

August 20 1941 January 23, 1942

Figs. 558, 559 Same as Figs 554–557 after insertion of the nail. Good position of fragments. Coxa vara corrected. Left the hospital after 4 weeks.

Figs. 560 561 Same as Figs. 554–559 after 5 months. Coxa vara recurred because of the obliquity of the fracture and because the nail was inserted too far laterally and because no continuous traction was used. Shortening 3 cm. If the nail had been inserted on the medial side of the greater trochanter as in Figs. 564–568 the coxa vara angulation would not have become so marked even without continuous traction.

Incision and insertion of the awl A 2 cm long skin incision is made 4–5 cm above the tip of the greater trochanter which can be readily palpated in the above described position. Through this incision the awl is inserted and the ridge of the greater trochanter is palpated with the tip of the instrument At the junction between the middle and the posterior third a hole is drilled through the hard cortex

Figs. 570, 571 *Compound* spiral fracture of left femur with 13 cm long butterfly fragment. This 42 year-old railroad worker was knocked down by a train. Wound excision, medullary nailing. Pin traction with 5 Kg for 2 weeks. After 3 weeks the leg rotated outward 90°. The leg was rotated inward around the nail under general anesthesia and a hip spica was applied for 8 weeks.

Figs. 572, 573 Same as Figs. 570 and 571 after 4 months. Bony union in good position without shortening. If the butterfly fragment had been held in place by 2 wire loops after wound excision and nailing, no continuous traction and no plaster cast would have been necessary.

Insertion of the guide pin The guide pin is then inserted into the medullary cavity through the hole made with the awl, by means of the handle (Fig 82). If this becomes difficult one may use the hammer. Great resistance usually indicates that the pin is taking a wrong course and has become caught in the cortex (Figs 183, 187). Therefore the path of the guide pin must be followed by the fluoroscopist. If it is introduced too far laterally the bone may be split later by the nail (Figs 190, 191). To prevent such incidents as shown in Fig 187, it is essential to use lateral fluoroscopy. If the fluoroscope shows that the cavity has been reached the guide pin is driven toward the fracture. The position must again be checked with the fluoroscope for assurance that the pin is not emerging through the fracture line. If this happens, the pin must be retracted and the distal fragments moved parallel by 2–3 mm towards the side at which the pin emerged and slightly angulated towards this direction. In this way one usually succeeds in introducing the pin into the medullary cavity of the distal fragment. As soon as the pin has passed the fracture by 2–3 cm, the angulation must again be corrected under X ray control to obviate such a condition as shown in Fig 185. Great difficulty with the introduction of

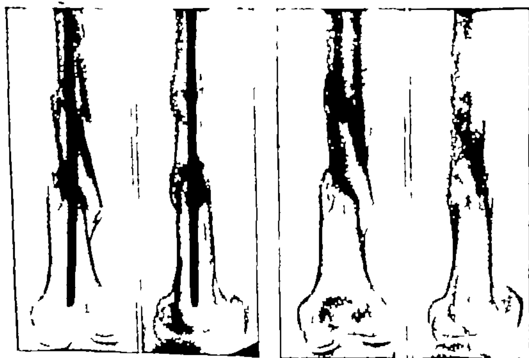


Fig 578 Fig. 579 Fig 580 Fig. 581

December 19 1942 February 18 1943

Figs. 578, 579 Same as Figs. 576 and 577 after 17 months. Bony union with good alignment of the main fragments. In the A P view the middle fragment lies obliquely as in Figs. 692 and 693 E, II/2040, 2041. Shortening 2 cm.

Figs. 580, 581 Same as Figs. 574 and 575 after one and a half years. Both fractures show bony consolidation. All joints free. Muscles strong.



Fig. 570 Fig. 571

February 12, 1942



Fig. 572 Fig. 573

June 1 1942

506 and 606) results or the nail may plow through the lateral wall of the greater trochanter as in Figs 741 and 765 If the guide pin and the nail are inserted on the outer side of the femur below the trochanter the bone may split as in Figs 190 191

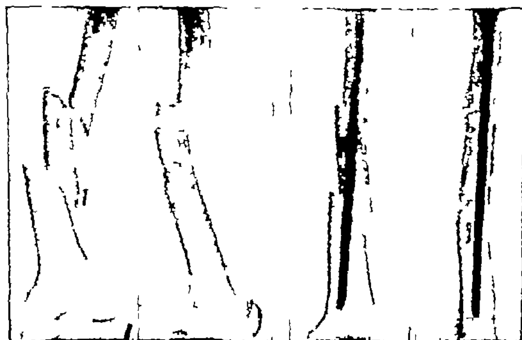
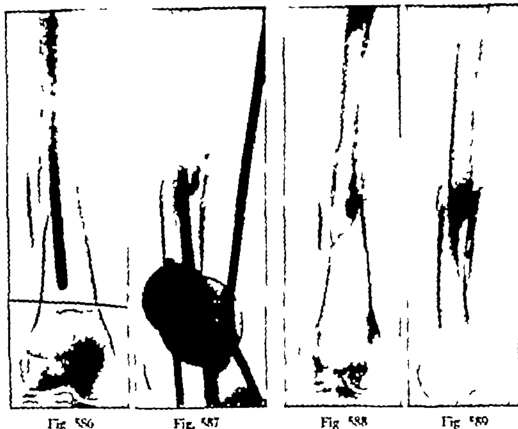


Fig 574 Fig. 575 Fig 576 Fig 577

July 2, 1941 *July 25 1941*

Figs. 574 575 Fragmented fracture of the left femur with 12 cm. intermediate fragment. The 38-year-old railroad worker weighing 63 Kg. was knocked down by a locomotive Pin traction with 9 Kg.

Figs. 576, 577 Same as Figs. 574 and 575, immediately after nailing 23 days after injury Gaping of distal fracture which was then impacted. Unna paste traction on the lower leg with 5 Kg for 8 weeks. Knee exercises were started in the 2nd week.



Figs. 586, 587 Same as Figs. 582–585 after 3 weeks. To prevent recurrence of shortening and angulation wire traction was applied to the femur with 7 Kg. weight

Figs. 588, 589 Same as Figs. 582–585 after 5 months. Well healed without shortening and with good alignment. The nail was useless because it was too short With continuous traction alone the same result could have been obtained in the same period of time

separated as in Figs 534 535 576, 577 and 595, they must be approximated by blows with the flat hand or with the fist upon the heel or upon the flexed knee other wise, callus formation will be delayed

If the fragments were not in exact position before the insertion of the guide pin and the nail (Fig 185), angulation persists (Figs 419 594, 595) If this occurs, serious damage results later (Figs 639 640) Bending the fragments with a Phelps Gocht (Fig I 108) is very difficult because the strong nail offers great resistance It is therefore important that all angulations be eliminated before the introduction of the nail

Post-operative positioning It is best to place the leg on a Braun leg frame The foot is suspended with a triangle bandage to prevent outward rotation (Fig II/2641) In order to recognize rotation immediately it is important that the leg frame should be horizontal (Figs 227–231) For this a hard bed-surface is needed (fracture boards under mattress Figs. 53 E I 65 and 70 E I 91) In soft beds, the leg frame slants and rotation may readily be overlooked

Supplementary External Support If transverse fractures and short oblique frac tures above the middle within the narrowest area of the medullary cavity, are provided with a nail of sufficient length and thickness as in Figs 108–120 and 540–553,



Fig 582 Fig. 583 Fig 584 Fig 585

December 23 1942 December 23 1942

Figs. 582 583 Nailed spiral fracture of the right femur with a 6 cm. butterfly fragment, treated elsewhere. This 47 year-old farmer's wife with infantile paralysis fell at work. Bone decalcified. The nail is much too short. It was inserted without previous correction of angulations.

Figs. 584 585 Same as Figs 582 and 583 after correction of angulations which was easily performed because the nail was too short.

the pin may be encountered in fragmented fractures (Figs. 133–137, 574–581 649–656) sometimes however these additional fragments align themselves quickly

Driving the nail As soon as the guide pin is found in good position, the nail is driven in over it If the fragments are separated (Figs. 534, 535) the traction is released When the nail enters the fracture area, its course must be followed closely by the fluoroscopist in both planes If a slight lateral displacement persists, as in Fig 400 the nail may be caught in the cortex. If it is not retracted it may split the bone (Fig 483) As soon as the head of the nail approaches the skin incision, the driving punch with a recess 2 cm deep (Fig 75) is placed over it for further driving When the punch touches the bone the head still protrudes 2 cm and the tip is 2 cm. removed from the knee joint.

Skin Suture The skin is then closed with two sutures and covered with a sterile dressing

X ray Control After the nail has been inserted and the wound closed X ray pictures must be taken exactly from the front and from the side to determine the position of the fragments and the position of the nail at the fracture and at the distal end, otherwise incidents such as shown in Figs. 186 189 and 769 may be overlooked.

Impaction of the fragments and straightening of the bone If the fragments are



Figs. 586, 587 Same as Figs 582 585 after 3 weeks To prevent recurrence of shortening and angulation wire traction was applied to the femur with 5 Kg weight

Figs 588 589 Same as Figs 582 585 after 5 months. Well healed without shortening and with good alignment. The nail was useless because it was too short With continuous traction alone the same result could have been obtained in the same period of time

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Supplementary External Support If transverse fractures and short oblique fractures above the middle within the narrowest area of the medullary cavity are provided with a nail of sufficient length and thickness as in Figs 108–120 and 540–553,



Fig 590 Fig. 591 Fig. 592 Fig 593

September 9 1941 September 9 1941

Figs. 590 591 Fracture of the right femur 6 cm. above the knee joint with unusual forward angulation. The 33-year-old workman was struck on the femur by a 200 Kg. lead plate.

Fig 592. Same as Fig 591 The fragments are distracted much too far This caused recurvation therefore the nail emerged behind the distal fragment.

Fig. 593 Same as Fig. 592 By strong traction it was possible to manipulate the nail into the distal fragment.

weight bearing may be initiated after one to two weeks without additional external support exactly as in correctly nailed fractures of the neck of the femur (see page II/916)

In fractures below the middle resting of the leg on a Braun frame is sufficient provided the nail reaches into the epiphyseal line These patients must not get up for four weeks

Supplementary continuous traction Transverse fractures immediately below the greater trochanter (Figs 554–569) can be safeguarded against angulation only by continuous traction (Figs 562–569) Without this, a coxa vara (Fig 560) will develop in spite of good reduction and a sufficiently long and thick nail because the medullary cavity is already very wide in this region (Figs 1–9)

Fragmented fractures are particularly suited for medullary nailing (Figs 133–137, 574–581 649–656) Without additional continuous traction however shortening will occur

Spiral fractures in the proximal third with a butterfly fragment (Figs 161–168, 570–573) can never be retained in good position with a medullary nail alone The muscle pull and the position on the Braun frame lead to an over riding of the fragments and thus to shortening and angulation even if the nail was long and thick enough In Figs 161–168 the nail was too short Such cases must receive additional skeletal traction If the nail is too short as in Figs 582–589 it provides no fixation whatever in spiral fractures of the lower third with a long butterfly fragment. This type of fracture should not be treated by nailing, but with continuous traction from the very beginning



Fig 594 Fig 595 Fig 596 Fig 597

September 9 1941 October 10 1941

Figs. 594 595 Same as Figs 590–593 after the nail was driven in further A valgus and an antecurvation of 15 each persist This was corrected with a Phelps Cocks All the difficulties arose from the fact that the fragments were distracted too far during the insertion of the nail

Figs. 596, 597 Same as Figs 590–595 after one month. Good position of the nail and good alignment in the cast



Fig. 598 Fig 599 Fig. 600 Fig 601

November 26, 1941 July 6 1942

Figs. 598 599 Same as Figs. 590–595 after 11 weeks. Good callus formation.

Figs. 600 601 Same as Figs. 590–595 after removal of the nail and 10 months after the accident. Bony consolidation. Knee 175–125 against 175–55 on the left Other joints free Valgus and antecurvation each 5–6

Traction with 4–5 Kg is sufficient because the nail does provide a certain fixation The effect of the traction must be checked by X ray pictures after 2 days and later every 7–14 days Skeletal traction may be used at first later Unna paste traction with plaster cuff on the lower leg (see page II/852)

Supplementary Plaster Cast In fractures near the knee joint in which the posi






Fig. 602 Fig. 603 Fig. 604 Fig. 605

December 30 1941 December 30, 1941

Figs. 602, 603 Fracture of the right femur stump with varus and antecurvation of 20° each. Marked decalcification.

Figs. 604, 605. Same as Figs. 602 and 603 after nailing. Varus angulation of 10° in A-P view good alignment in lateral view

tion was corrected after the insertion of the nail, as in Figs 594–597, a supplementary circular plaster cuff from the ankle to the hip joint is necessary If the fracture is more than 7 cm. removed from the knee joint, a hip spica must be applied because a leg cast would not provide sufficient support if the nail is too short, as shown in Figs. 234–243 If the nail reaches into the epiphyseal line as in Figs. 695, 696, no additional plaster cast is necessary *As a rule supplementary traction and casts are necessary only if the indication for nailing and the technique were inadequate*

Exercises Toe and ankle must be exercised actively throughout the full range from the first day on Active motions of the knee or hip joint may be started after one week when the swelling and the hematoma have subsided If these joints are exercised during the first few days as many propose pain appears the knee becomes hot, and the swelling recedes much more slowly It may even lead to inflammation at the fracture site and at the nailing site It must be emphasized again and again that the knee joint never suffers the slightest damage from an immobilization of one to two weeks but does so from premature motions which usually cause pain.

The old axiom that vigorous massage and forcible passive motion in all fresh and in most old injuries are extremely detrimental (see page I/37) holds good for

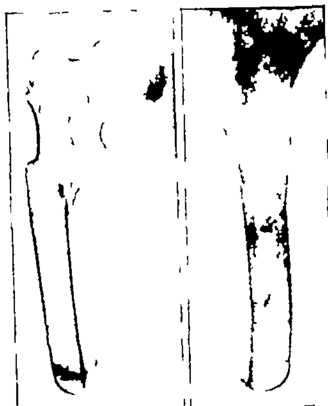


Fig. 606 Fig. 607

June 25 1943

Same as Figs. 602–605 after one and a half years. Bony union with varus of 20° because the nail was inserted too far laterally. Good lateral alignment.

medullary nailing as well. That this may cause exuberant callus formation and permanent limitation of motion is shown in Figs 408–415 The rule **Exercises must never cause pain,** (see page I/31), applies equally to medullary nailing

In fractures which require additional traction (see Figs 161–168, 554–581, 649–656), skeletal traction should be replaced after 2–3 weeks by Unna paste traction with a plaster cuff and the patient should then exercise the knee twice daily on the knee-exercise frame (Figs. II/1574, 1575 and 680, 681 E, II/1611, 1612), at first for half an hour, later for one hour The nail provides sufficient stability to prevent redisplacement of the fragments during this period After the exercise traction should be continued In long spiral fractures, continuous traction must be maintained for 6–8 weeks or angulation will recur, as shown in Figs 161–168 After this period the knee can be actively moved to a right angle and the muscles will have become strong if the exercises were carried out faithfully

Hospitalization Patients with suitable transverse fractures (Figs 108–120) and short oblique fractures (Figs 540–553) between the proximal and middle third may leave the hospital after 2–3 weeks without any additional support Those with fractures below the middle should be hospitalized for 5–6 weeks and those with long spiral fractures for 8–9 weeks.

Duration of treatment Young patients with transverse fractures or short ob-

lique fractures in a favorable location may resume regular work after 8–10 weeks even if marked displacement was present They may perform light work after 3–4 weeks Those with less favorably located fractures may return to work after 3–4 months, if no complications set in

Follow-up After discharge from the hospital, patients should return every 1–2 weeks for a check up After they start to work they should return every 2 months for an X ray check up Separate records should be kept for nailed frac tures (see page 54) to make sure that this regular follow up is not overlooked

Removal of the nail The nail must not be removed until the fracture shows X ray evidence of firm consolidation At least 6 months should elapse before re moval. Before this, the nail is sometimes still very firmly embedded If it is removed after merely 8–10 weeks, the bone may bend again After 6 months or more extraction is usually very easy under local anesthesia Formerly we per formed this procedure in the out-patient department However, since a hematoma develops in some cases, we now admit the patients to the hospital for a few days. At any rate the extractor of Küntscher (Fig 71), Pohl, or Stör (Fig 83), and the clamp of Jörg Böhler (Fig 84) must be in readiness. The difficulties which may be en countered in the extraction of freshly driven nails are discussed on pages 55–57

Complications of Closed Medullary Nailing of the Femur

The various types of incidents which may occur during medullary nailing have been discussed on pages 74–89 They are most commonly due to incorrect indi cation (operating during shock), or to lack of necessary equipment such as reduction apparatus, 2 X ray machines an adequate choice of nails, extractors, etc

Next to fatalities the most distressing incidents are those due to the use of too thick a nail or to the lack of effective extractors because the operation must then sometimes be interrupted (see pages 55, 56 and 79–81)

Even if everything is on hand many incidents arise from insufficient reduction before the guide pin is introduced (Figs 185, 187–191 390–397 416–423 590–601)

In Figs 416–423 the extensive periosteal appositions would not have developed had the angulation been eliminated before the introduction of the guide pin this could easily have been accomplished on the reduction apparatus with the knee flexed, if adequate X ray pictures had been taken

Truly great difficulties arose in the case of Figs 590–600, because traction was so excessive that the fragments separated This caused a lateral displacement and angulation and a deviation of the nail which could be brought into the medullary cavity only by additional traction This caused further angulations All these incidents could have been avoided if X ray pictures had been taken after reduction A close inspection should have revealed the gap between the fragments and the angulation and both should have been corrected before the introduction of the guide wire and the nail

The majority of incidents are due to the use of too short a nail This causes shortening and bowing (Figs 161–168 390–397 400–407 582–589) rotational redis

placement (Figs 222–229) migration of the nail (Figs 231–243) and a new fracture with the nail in situ (see page 87) Marked periosteal appositions which were previously interpreted as desirable callus formation produced by the nail, develop only because the short nail does not adequately immobilize the fragments (Figs 390–397 400–407)

Results

The results are surprisingly good (Figs 108–120 540–553) in correctly selected cases if the operation has been properly timed (omission of operation during shock or in the presence of unhealed wounds and marked swelling) and the technique is faultless (exact reduction before insertion of nail and use of a nail of sufficient length and thickness) The local circulatory disturbances subside rapidly, therefore muscle wasting decalcification and restriction of motion do not develop provided no forcible passive movements and no vigorous massage are used General circulatory disturbances do not occur as a rule The hospital stay is very short (2–3 weeks) under favorable circumstances The ability to work is restored in a short time No permanent damage results

Causes of Failure in Closed Medullary Nailing of Femoral Fractures

1 **Operation during shock This may cause death** Medullary nailing is not an emergency measure
2 Operation in the presence of swelling and fever Medullary nailing is not an emergency measure
3 Operation before wounds on the injured leg or in other parts of the body have healed (i e , within 2–3 weeks), if it was not possible to perform the operation within the first few hours Medullary nailing is not an emergency measure
4 Operation in joint fractures
5 Operation in fractures which are less than 7 cm removed from the knee joint or from the tip of the greater trochanter
6 Operation without essential instruments (guide pins and nails of sufficient length and thickness extractors etc —see pages 22–26)
7 Operation without reduction apparatus
8 Operation with one instead of two X ray machines
9 Omission of local anesthesia when the initial X ray pictures are taken, because the leg can usually then not be positioned properly for a strictly lateral view
10 Omission of the exact determination of the length, width and curve of the medullary canal
11 Failure to check the length and size of the guide pin and of the medullary nails and their matching
12 Failure to protect the patient against heat loss
13 *Omission of exact reduction of the fracture before the introduction of the guide pin*
14 Failure to check the position by X ray pictures before the introduction of the guide pin (Figs 186–189 390–397 400–407 590–601)

15 Failure to check the progress of the guide pin by fluoroscopic control
16 Insertion of the guide pin and of the nail on the lateral side instead of on the medial side of the greater trochanter, this causes a varus angulation
17 Failure to check the progress of the nail by fluoroscopy during its insertion
18 Fluoroscoping without lead gloves and lead apron
19 Omission of X ray pictures after insertion of the nail
20 Omission of axial impaction of the fragments
21 Failure to place the leg on a Braun leg frame
22 Use of a bed without a fracture board
23 Omission of supplementary traction in high transverse fractures, in comminuted fractures, in spiral fractures with a long butterfly fragment and in fragmented fractures.
24 Omission of supplementary plaster cast if too short a nail has been used.
25 Premature knee exercises, i e , within the first week
26 Use of vigorous massage and forcible passive motion This leads to periosteal appositions and to limitation of motion (Figs. 408–415)
27 Neglect of continuous observation and X ray controls until the nail has been removed
28 Failure to use a special record file of medullary nailing cases.
29 Premature removal of the nail, i.e , before the fracture shows firm union roentgenologically and before six months have elapsed
30 Neglect of X ray checkups at the conclusion of the treatment.

Open Medullary Nailing of Fresh Closed Fractures of the Femur

By means of our reduction apparatus (Figs 527–531), we have always succeeded in reducing the fragments of closed femoral fractures satisfactorily for closed medullary nailing

Some surgeons have suggested that the fragments should be exposed if reduction cannot be obtained promptly and that open medullary nailing should be performed. If this is done the greatest advantage of the closed medullary nailing viz , minimization of the danger of infection, the most precious virtue of Küntscher's method, is lost.

Exposure of the fragments should be rejected if their reduction was not obtained successfully after hours of effort or if an impacted nail had to be extracted with great difficulty These violent reduction and nailing maneuvers cause additional injury to the muscles and to the skin in the region of the fracture which increases the danger of infection Furthermore the asepsis may suffer because sometimes the preparation of additional instruments, the assistance and the draping etc. have been improvised This has often been followed by infection This most *serious complication can be avoided because as must be repeatedly emphasized*, medullary nailing is not an emergency measure which has to be employed under unfavorable external circumstances The prophylactic use of penicillin may prevent infection in open medullary nailing

If closed reduction is unsuccessful a Steinmann pin or Kirschner wire should be applied Continuous traction may be used until bony union has taken place Even with interposition of soft tissues the danger of pseudarthrosis is slight if traction is not excessive (Figs 307–316) In children I have never seen a pseudarthrosis of the femur, even if traction was excessive

Under the protection of penicillin we have lately used open medullary nailing in closed spiral fractures of the femur, uniting the fragments with 1 or 2 supplementary circumferential wire sutures as in Figs 671–678 Open nailing may be performed on the day of injury before a large hematoma or swelling develops, if the injured is in good general condition and not in shock Otherwise the nailing is performed after the swelling has subsided, i e , after 8–10 days This procedure is much to be preferred to violent reduction maneuvers in difficult cases

If great difficulty with closed reduction as in Figs 562–569 is foreseen, then it is best not to attempt it

Open Medullary Nailing of Fresh Compound Fractures of the Femur

In a compound fracture the danger of infection lurks because the fracture has been exposed by the accident. The question arises whether medullary nailing decreases or increases this hazard Up to date I have rejected the former methods of osteosynthesis for compound fractures of the femur, because they required wide exposure of the fragments and did not provide sufficient stability, as shown in Figs 136 E, I/196, II/2094–2105 and II/2138 With Küntscher's method these two objections are not valid. Therefore I use the nail in all compound fractures of the femur which do not involve a joint if the general condition is satisfactory

General preparation of the patient The patient is frequently in severe shock, with pale and cold skin and mucous membranes, with weak and rapid pulse He must be protected from further loss of heat, must be rubbed with warm cloths, covered warmly and given hot drinks

Detailed examination of the patient While the patient is being thus treated, the extent of the injuries should be accurately determined The pulse on the dorsum of the foot and behind the internal malleolus should be examined, keeping in mind that in shocked and exsanguinated patients the pulse is frequently not palpable on either foot. If it is absent on the injured side only, it is an indication that the main artery is either torn or blocked by compression from one of the fragments. The motion of the toe and foot joints as well as the sensation and the reflexes should also be examined

Local anesthesia This examination should be brief so as not to delay anesthesia by injection of 0.5 per cent novocaine solution into the fracture The deadening of pain improves the general condition and the pulse becomes stronger and slower

Infusion or transfusion If the patient does not respond satisfactorily to external heat oral fluid intake, and local anesthesia, he is given an infusion of 500 cc. of an isotonic solution of blood serum salts, and preparations are made for blood transfusion

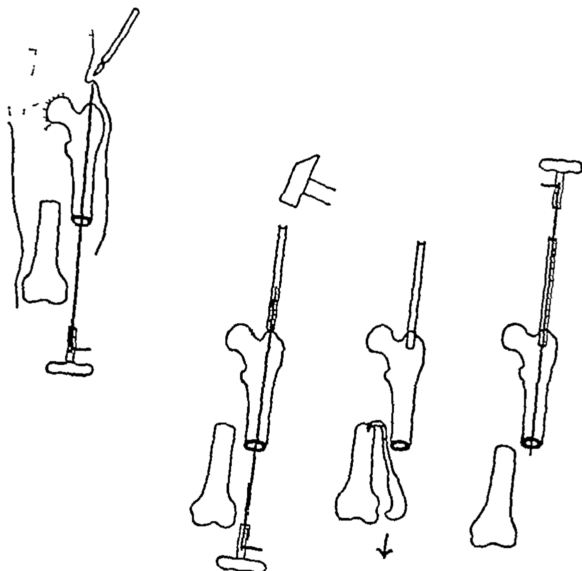


Fig 607 a–d

Fig 607 a. In the open medullary nailing the guide pin is inserted into the proximal fragment from below and pushed through the greater trochanter Where it bulges the skin, a 2–3 cm. incision is made.

Fig. 607 b. A short medullary nail is slipped over the guide pin and pushed down to the greater trochanter

Fig 607 c. The short nail is driven 1–2 cm. into the greater trochanter The guide pin is pulled out from below The shortening is corrected with a single pronged hook.

Fig 607 d. Another guide pin is inserted from above through the short medullary nail.

X-ray examination When the patient has recovered X ray pictures should be taken in both planes to determine the type and extent of the bone injury

Amputation If the leg remains pulseless cool pale and without sensation, even though the patient has recovered it must be amputated

Instruments and apparatus For open medullary nailing the instruments pictured in Figs 85–91 are needed in addition to those enumerated on pages 22–26 for the closed nailing A reduction apparatus is not necessary and only one X ray machine is needed not two

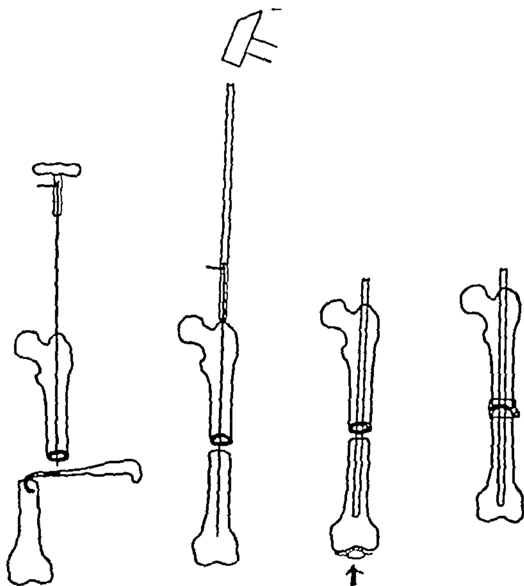


Fig 607 e–h

Fig 607 e By pull and pressure with a single-pronged hook the lateral displacement is corrected.

Fig. 607 f. After exact reposition the guide pin is pushed towards the knee joint. The medullary nail of proper length and thickness is driven in with a hammer

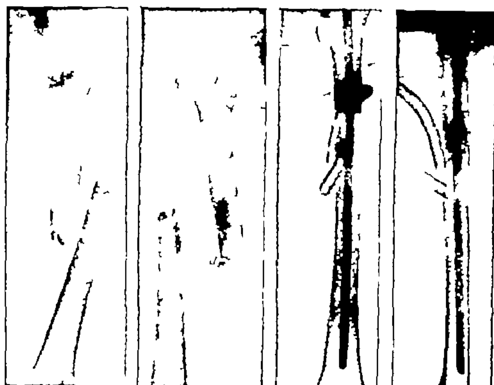
Fig 607 g. The nail has been driven to near the knee joint. The fragments are impacted.

Fig. 607 h. The fragments have been impacted and are secured against rotation by a wire loop

Determination of the length width and curve of the medullary canal The procedure given on page 40 serves to determine the required thickness and length of the medullary nail

Debridement This must be carried out thoroughly in the manner described on pages I/112–130 To reach all the pockets and recesses of the wound the skin wound must be extended by appropriate incisions Soiled bone should be cleaned with chisel and rongeurs This may take an hour or more

Heat protection During this period the patient must be carefully protected against heat loss Pulse and general appearance must be observed continuously



Figs. 608 609 Compound transverse sheared fracture of the left femur with shortening of 6 cm., lateral displacement by double shaft s thickness and angulation This 48-year-old woman was knocked down by a truck suffering also a cerebral concussion, laceration of the upper lip fracture of the right internal malleolus and of the right second to seventh ribs with hemothorax. Wound excision under local anesthesia and medullary nailing. Unpadded plaster cast for the fractured malleolus was split immediately

Figs. 610 611 Same as Figs. 608 and 609 immediately after nailing. Very good position of the fragments. Two rubber drains plainly visible.

Blood transfusion If the pulse and the general condition do not improve, a blood transfusion of 400–500 cc. is given

Continuous traction If the general condition of the patient does not respond to these measures a pin or wire is inserted for continuous traction to terminate the operation quickly

Open nailing If the pulse recovers, the guide pin is inserted into the proximal fragment from the fracture site and pushed through the greater trochanter and the skin Over this pin a short medullary nail is driven 1 cm. deep into the greater trochanter (Figs. 181 182) The guide pin is then again removed through the wound and a new guide pin is inserted through the short medullary nail which served as a temporary guide and which is then removed After this guide pin appears in the fracture, both fragments are grasped with a Lambotte bone clamp or with strong bone hooks and coapted The guide pin is then pushed into the distal fragment.

X ray pictures In order to determine whether the fragments are well aligned without angulation and whether the guide pin is correctly located, biplane X ray pictures must be made

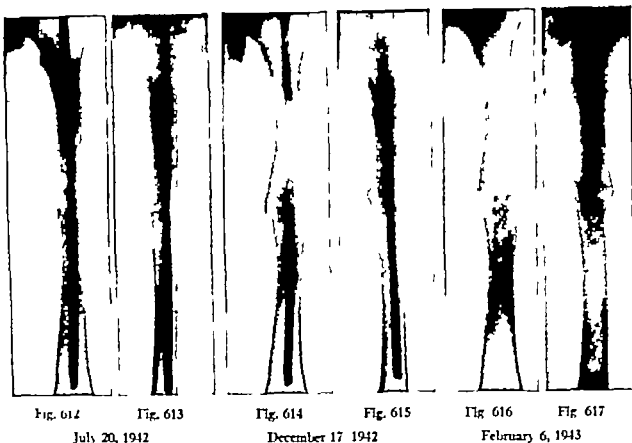


Fig. 612 Fig. 613 Fig. 614 Fig. 615 Fig. 616 Fig. 617

July 20, 1942 December 17 1942 February 6, 1943

Figs. 612, 613 Same as Figs. 608–611 after 7 weeks. No callus visible. Got up after 5 weeks with walking cast on right leg and Unna boot on left leg. Left the hospital after 7 weeks. Walking cast removed after 10 weeks.

Figs. 614 615 Same as Figs. 608–611 after 6½ months. Good callus formation on the medial side, anteriorly and posteriorly

Figs. 616, 617 Same as Figs. 608–611 immediately after extraction of the nail and 8 months after the accident. All joints of both legs show full range of active motion. Muscles strong. No discomfort.

Nailing If the X ray pictures show that everything is satisfactory, a nail of proper length and size, as determined in the manner discussed on page 166, is driven in over the guide pin until only 2 cm of it is left protruding from the greater trochanter. If the fragments are not then immobilized perfectly, as in spiral fractures at the proximal or distal ends (Figs 570–573 582–589, 671–678), they are secured by one or two circumferential wire sutures. In comminuted fractures (Figs 618–633), supplementary continuous skeletal traction with a pin or wire must be applied.

X ray control New biplane X ray pictures are then taken with the central ray focused over the knee joint line, to determine positively whether the point of the nail is too close to or too far from the knee joint.

Insertion of drains After the X rays show satisfactory position, one or more rubber tube drains are inserted into the deepest parts of the wound (Figs. 610, 611 620 621)

Wound closure After thorough debridement and if the wound is no more than 6–8 hours old the skin and the skin only is closed with sutures. No sutures or ligatures are buried in the wound. Only if nerves have been severed is an exception



Fig. 618 Fig. 619 Fig. 620 Fig. 621
January 22, 1942 January 22, 1942

Figs. 618 619 Compound comminuted fracture of the right femur in a 20-year-old blacksmith whose right leg was caught in a metal-bending machine. The femur is comminuted in the middle for a distance of 17 cm The distal fragment is displaced posteriorly by 8 cm The greater part of the muscles is crushed through. Nerves and blood vessels uninjured Thorough excision of wounds 2 hours after injury through 2 longitudinal incisions, each 20 cm. long, on the anterior and posterior surfaces. The sheath of the sciatic nerve was cleaned by sharp dissection and the splinters were cleaned of dirt with a Luer rongeur Then insertion of nail, of 5 rubber drains, and skin suture without ligations or sutures in the depth of the wound. Healing without wound complications. Tibial pin traction with 5 Kg. for 10 weeks.

Figs. 620, 621 Same as Figs. 618 and 619 after nailing Good axial alignment in both planes. The 5 drains are plainly visible. Small skin necrosis.

Figs. 622, 623 Same as Figs. 618–621 after 3 months. The splinters have healed in Only a weak bridge in the middle Got up 3 weeks later and resumed his work 6 months after injury Varus of 5° Good lateral alignment The nail has neared the lateral wall. Knee motion 180–110°

Figs. 624 625 Same as Figs. 618–621 after 9 months. Varus of 10° Good lateral alignment. A cavity with sclerosed wall can be seen at the point of the nail.

Figs. 626, 627 Same as Figs 624 and 625 after another 4 months, and 13 months after injury The bridge of bone has become stronger but has broken through the middle. Varus of 10° recurvation of 5° No discomfort.

made to this rule If the wounds show a good red color they may be sutured loosely even after 24 hours. If penicillin is available its use should be begun immediately after the operation

Supplementary external supports such as plaster casts are not necessary if the fragments were encircled with wire in oblique and spiral fractures, especially in those with a long butterfly fragment. In the spiral fracture with a long butterfly fragment, shown in Figs 570–573 the leg would not have rotated if the third fragment had been fastened to the nail with one or two circumferential wire sutures This patient would then have needed neither a plaster cast nor continuous traction and



Fig. 622 Fig. 623 Fig. 624 Fig. 625 Fig. 626 Fig. 627

April 22, 1942 October 9 1942 February 18 1943



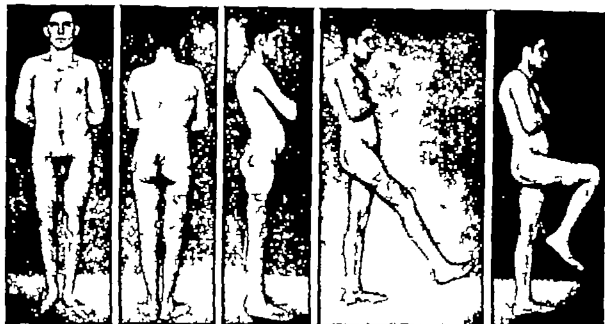
Fig. 628 Fig. 629 Fig. 630 Fig. 631 Fig. 632 Fig. 633

June 16 1943 July 14 1943 May 18 1944

Figs 628 629 Same as Figs 624 and 625 after 8 months and 17 months after injury The bony bridge has become stronger Fracture line begins to obliterate The nail has approached the posterior wall. Varus of 10° recurvation of 15 The entire track of the nail in the distal fragment shows a sclerotic lining Periosteal appositions on the lateral and posterior aspects

Figs 630 631 Same as Figs 628 and 629 after removal of the old nail, straightening of the bone and introduction of the new nail. Its point reaches to the epiphyseal line The angulations are corrected The fracture line has widened.

Figs. 632 633 Same as Figs. 630 and 631 10 months after the insertion of the new nail and 28 months after the injury No further bowing occurred The fracture line is now bridged by thick well-transformed bone fully adequate for weight bearing.



Figs. 634–638

February 17, 1943

Photographs of the case of Figs. 618–633 13 months after injury The circular muscle defect is still plainly visible. No shortening. Knee 180–60° Full active extension of the knee. Other joints free. Resumed his regular work as a blacksmith 6 months after injury his work required lifting pieces of metal weighing 100–170 Kg

could have gotten up after 3 weeks without additional bandage and all joints would have been freely movable In comminuted fractures, as in Figs. 618–621, supplementary continuous traction must be used.

Post-operative positioning The leg is placed upon a Braun leg frame as in closed medullary nailing (see page 179) and the foot is suspended. The bed must be firm (see Figs 53 E I/65 and 70 E I/91)

Exercises The toes and foot joints are actively exercised throughout the entire range from the first day on. After a week quadriceps exercises are begun, provided no wound disturbances are evident. Active exercises of the knee joint must not be started before 3 weeks and then only if the wounds have healed perfectly If these exercises are started earlier late wound infection may develop A warning must again be sounded against vigorous massage and violent passive motion.

Exercises must never cause pain (see page I/31)

Ambulation Depending upon the severity of the injury and the size of the wound, the patient may get up for the first time after 4–6 weeks. The man with the comminuted fracture of Figs 618–638 had to remain recumbent for 4 months

The hospital stay varies between 6 weeks and 4 months and is as a rule much shorter than with the previous treatments by continuous traction and plaster cast.

Subsequent observation Comminuted fractures must be closely observed New X ray pictures should be taken every month until the nail is removed

Results Of 16 fresh compound femur fractures treated with open nailing 15 healed without wound disturbances In one case the temperature rose after 10

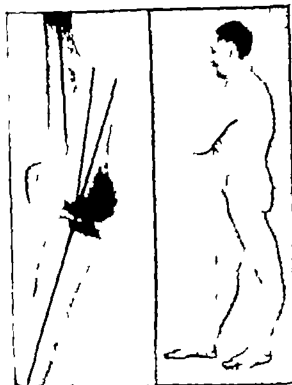



Fig. 639 Fig. 640

Fig. 639 X-ray of Fig. 640 Supracondylar fracture of the femur of 22 years, standing. Healed with recurvation of 12° which is less angulation than in the case of Fig 629 Due to this recurvation at the fracture site the knee was subjected to faulty weight-bearing for many years and hyperextended. Thus an additional angulation of 8° developed between the lower fragment and the lower leg, producing a total recurvation of 20°

Fig. 640. Photograph of Fig. 639 shows the markedly hyperextended appearance of the knee due to recurvation at the fracture site and at the knee joint. If the knee region is held at 180° there is marked lateral instability Limping gait.

days a superficial abscess developed which was opened whereupon the temperature subsided A sinus remained through which a small superficial sequestrum discharged after 5 months In this case, contrary to our general principles the muscles were approximated with a few sutures Since an infection did develop in one out of 16 cases this result must be considered inferior to the 23 compound femur fractures all of which healed without wound disturbance as reported by Ehalt in his book [10] The treatment however, has become greatly simplified

The severe compound comminuted fracture shown in Figs 618–638 followed a particularly interesting course After painstaking wound toilet and nailing, skeletal traction with 5 Kg was used for 10 weeks to prevent an approximation of the main fragments with shortening Although there was only a thin bridge of bone (Figs 622 623) the patient was able to get up after 4 months and to resume his hard work as a blacksmith after 6 months After 9 months the thin fragments showed bony union (Figs 624 625) After another 4 months, the X ray pictures showed an increase in the bone bridge but a fracture through its middle (Figs 626, 627) The patient had no discomfort because the nail provided sufficient stability This

[10] Ehalt Die Behandlung der offenen Brüche der langen Rohrenknochen und ihre Ergebnisse. Vienna, Maudrich 1938.



Fig 641 Fig. 642 Fig. 643 Fig. 644
September 1 1941 May 3 1942

Figs. 641 642. Compound fracture of the right femur with marked displacement. The 54-year-old work man fell into an elevator shaft Also contused laceration of the scalp and compound fracture of the right humerus. The proximal fragment protrudes 3 cm. through a 7 cm. long wound and is badly soiled. Ex cision of wound and bone debrided with rongeur Medullary nailing and draining Wound healed uneventfully Got up after 6 weeks

Figs. 643 644 Same as Figs. 641 and 642, after 8 months. The nail is somewhat too short. Bony union with strong callus. Antecurvation of 10°

fracture within the callus developed because the nail had not been driven in deeply enough and therefore had play in its distal sections as is evident from the area of condensation around the tip of the nail X ray pictures taken 17 months after injury show the bony bridge much strengthened and the fracture line narrowed At the same time it is evident that the bone bowed and that a varus angulation of 10° and a recurvation of 15° had developed (Figs 628, 629) Since such angulations cause late disturbances sometimes even after 10-20 years as shown in Figs. 639, 640 and as I have proven in my article in Der Chirurg' No 4 1942, it was decided to correct the deformity as the patient was only 20 years old For this purpose the nail was extracted under spinal anesthesia after the leg had been placed in Wittmoser's reduction apparatus A guide pin was then inserted and the bone straightened As soon as the biplane X ray pictures showed correction of the angulation a new slightly longer medullary nail was driven in. With this the patient got up after 8 days and resumed his work in 4 weeks. The fracture line was again distinctly visible (Figs 630 631) After correction of the angulations he walked better than before One year after the second nailing and two years after the injury, the fracture showed bony consolidation (Figs 632 633)

Without medullary nailing it would not have been possible within the compara tively short time of six months to restore a man with such a fracture to working capacity without shortening and with good mobility







Fig 645 Fig 646 Fig. 647 Fig 648

August 15 1942 May 3, 1942

Figs. 645 646. Same as Figs. 641 and 642, after one year Solid bony union Bone still thick.

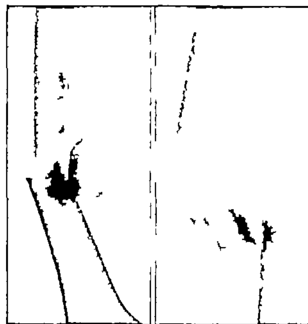
Figs. 647 648. Same as Figs. 641 and 642, after 8 months. Knee 170–70° against 180–50° on left. Muscles strong. Moderate discomfort

Fundamental considerations concerning the correction of angulations The goal in the treatment of femur fracture is union with the least possible shortening, good alignment and free motion These three aims can be accomplished in the simplest and surest way by the use of the medullary nail With continuous traction this goal can usually be achieved in fresh compound and closed fractures (Figs 708–721E, I/297–323 II/2016–2068) In old infected fractures, however, one must be very careful with an attempt at lengthening the bone and correcting angulations. As long as there is secretion the bone must not be refractured and lengthened simultaneously because this often leads to a flare up of the infection separation of sequestra delayed callus formation and stiffening of all joints (Figs 322–341) In such fractures the angulatory displacements should be corrected, but the shortening should be ignored Healing will be rapid and motion will be good The shortening can then be compensated for by a shortening of the well leg (Figs 705–734)

Open Medullary Nailing of Fresh Gunshot Fractures of the Femur

Gunshot fractures of the femur present one of the most difficult problems in war surgery The mortality is very great because technically it is extremely difficult to provide adequate and complete immobilization for transportation and for treatment especially in the presence of large wounds I therefore proposed in "Der Chirurg No 1 1943 to treat suitably selected cases with Küntscher's medullary nail

To date I have performed medullary nailing in two fresh gunshot fractures of



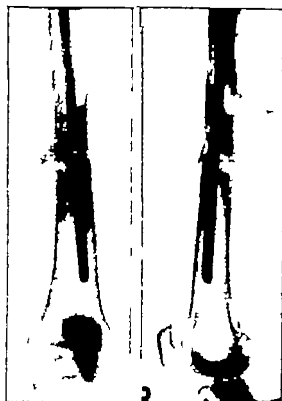


Fig. 649 Fig. 650 Fig 651 Fig. 652

November 27 1941 November 28, 1941

Figs. 649 650 Fragmented fracture of the right femur with an intermediate fragment of 6 cm. length. This 32 year-old cleaning-woman was knocked down by an exploding stove, suffering also a contused laceration of the scalp, extensive burns on the right femur in the groin on the abdomen and on the buttocks. Figs. 651 652. Same as Figs 649 and 650 after nailing under spinal anesthesia. The 3 fragments are in good apposition. Additional pin traction of 8 Kg. After 3 weeks, the fractures which in the meantime had become infected were exposed by 2 incisions.

the femur The result was satisfactory in the first case (Figs 671–683) and excellent in the second (Figs. 657–670)

Case 1 A 21 year-old man was wounded on Sept. 26 1942 at 10 30 a.m. by multiple shell fragments and was admitted to a field-station at 9 30 p.m. after a difficult transport through mountainous terrain He had suffered an entry wound 1 cm. in size 3 cm. medial from the anterior superior iliac spine a 0.5 cm. entry wound on the outer side of the middle of the right thigh, a 1 cm. entry wound about a hand s breadth above the right knee joint on the lateral side and a 1.5 cm. entry wound on the antero-lateral aspect of the lower leg between the proximal and middle third with peroneal paralysis.

The femur was fractured X ray pictures (Figs. 671 672) showed a spiral fracture 16 cm. long beginning 8 cm. above the joint and running upwards On the medial wall of the medullary canal a shell fragment of 9 mm. diameter and nearby one of 2 mm. diameter were seen. Marked abdominal rigidity was present.

Because of the symptoms of intraperitoneal injury the abdominal wound was exposed by Prof Frey The track led through the peritoneum. After enlarging the wound the sigmoid was found uninjured but intestinal contents were found in the peritoneal cavity Therefore a midline incision from the umbilicus to the symphysis was made. Three openings were found in the lower ileum discharging intestinal contents These were sutured. The cavity was cleansed with damp sponges. Both abdominal wounds were then completely closed.

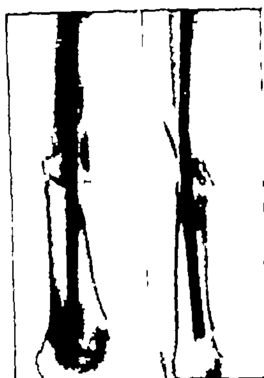




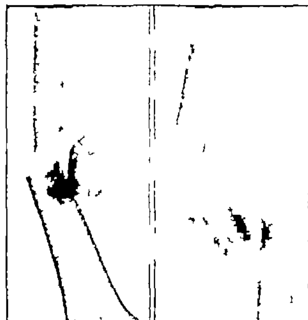
Fig. 653 Fig 654 Fig. 655 Fig 656

July 1, 1942 November 5 1942

Figs. 653 654 Same as Figs. 649–652, after 8 months. Several sequestra separated from the intermediate fragment these were removed after this picture was taken. The burns in the groin were covered 4 months later with Reverdin grafts.

Figs. 655 656. Same as Figs. 649–652, after one year Bony union in good position. Both fractures show bony consolidation. Knee 167–150° Other joints free. Shortening 1 cm.

Since the general condition was still satisfactory at 10 30 p.m. and since the three wounds on the right leg showed no signs of inflammation, I decided upon medullary nailing At first the wound on the middle of the thigh was excised It reached only 1 cm. into the muscles The wound on the lower leg was severely lacerated and penetrated into the interosseous space. After sponging there was profuse bleeding and the anterior tibial artery was found torn and was ligated Both wounds were left open The wound above the knee joint was extended to 13 cm The torn muscles were excised carefully down to the bone The distal fragment showed a caliber size hole at the lower end of the fracture line (Fig 672) which was enlarged with a rongeur This permitted the removal of two metal splinters and of a small piece of cloth from the medullary cavity After thorough wound toilet, a guide pin was inserted into the proximal fragment until it protruded from the greater trochanter Over this a medullary nail of medium size and 40 cm. in length was driven in. Since the hammer was too small the driving did not progress and I was obliged to get a heavy hammer from a tool chest and have it sterilized. With this it was possible to drive the nail to the fracture site whereupon both fragments were held together with a strong bone forceps and the nail was driven into the distal fragment. The fracture was not firm however because the nail entered the distal medullary cavity which was here 40 x 50 mm. in size only for a distance of 3 cm. It was still 5 cm. removed from the knee joint. The nail should have been 3–4 cm. longer I therefore encircled the fragments with a wire making the fracture firm. A rubber drain was inserted and brought out posteriorly (Figs 673, 674) A sulfa compound was dusted into the wound which was closed with 5 skin sutures without ligatures or deep sutures. The original round wound 1 5 cm in diam. was left open The nailing site above the trochanter was not sutured. Post-operative pulse rate was 110 slightly irregular 400 cc. of blood plasma was infused. The leg was placed on a Braun leg frame. Duration of debridement was 65 minutes duration of nail



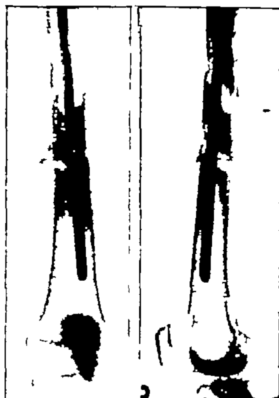


Fig. 649 Fig. 650 Fig. 651 Fig. 652

November 27 1941 November 28, 1941

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Knee 170 145, hip one-third restricted (Figs 679-683) X ray pictures (Figs 677 678) show bony union of the fragments in good position The periosteal appositions have partly receded The torn wire loop can still be seen Several small sequestra are noted requiring removal

June 10 Removal of thin superficial sequestra more than 8 mm in size The sinus closed three weeks thereafter

June 2 1944 The sinus on the femur did not break open in spite of heavy work No abdominal symptoms. No active extension of the great toe but the other toes and the ankle joint show full range of active motion Right knee 180-110 against 180-40 on the left Hip joint free

Case 2 A 22 year-old man suffered machine gun wounds on Oct 4 1942 at 6 30 a m and was admitted at 8 p.m in good general condition The left femur was broken the leg rotated outward and shorter by 3 cm He had an entry wound of 14 x 18 mm in size located anteriorly 15 cm above the patella, and two exit wounds 4 cm apart postero laterally one 12 cm the other 13 cm below the greater trochanter One was 6 x 9 mm. the other 10 x 13 mm in size X ray pictures showed a long spiral fracture with a butterfly fragment between the proximal and middle third (Figs 657 658)

Since the wounds were still clean I decided to excise them and to perform the medullary nailing although 14 hours had elapsed since the injury The anterior wound was extended 15 cm and the skin and the fat excised After opening the fascia, the muscles showed extensive lacerations in both directions. In order to reach all torn muscle stumps the incision had to be extended to 30 cm After meticulous excision of the torn muscle fibers the blood clots were sponged out of the medullary canal. The long third fragment was connected with the muscles and the periosteum Its attachments were not severed After thorough cleaning of this wound the hemostats were removed Only one vessel continued to bleed and was ligated The skin was closed with towel clips The patient was then placed on his side and the posterior wounds were excised The lateral wound was extended 20 cm the medial 10 cm Skin and fat tissue as well as the torn muscles were excised accurately down to the fracture No ligations were necessary After dusting a sulfa compound into the wounds and into the medullary cavity a guide pin was pushed into the proximal fragment and brought out through the greater trochanter The nail was driven in over it until it appeared in the fracture. The two fragments were then coapted accurately by traction and strong bone clamps The nail was then driven in until it protruded only 3 cm. from the greater trochanter The two main fragments were thus firmly united against torsion bending and longitudinal displacement, whereas the third fragment was only in loose apposition A large drain was inserted into both the posterior and anterior wounds. Again sulfa was dusted into all three wounds which were then closed with skin sutures without deep sutures The wound at the nailing site was left open and covered with a small sterile dressing After removing the blood which had oozed into the wound during closure a pressure bandage was applied to the femur and the leg was placed on a Braun frame Duration of debridement was 65 minutes nailing 10 minutes skin sutures 10 minutes total, 85 minutes.

X ray pictures showed good position of the fragments and of the nail (Figs. 659 660)

Oct. 5 a.m. Temperature 37 9°C pulse 130 appearance good feels well. No pain in femur Evening temperature 38.2 pulse 120

Oct. 6 No pain. Temperature a.m 37 4 C P m 37 7 C

Oct. 7 No pain Temperature a.m. 37.2 C p.m 38 1 C pulse 100 Change of dressing The wounds showed no reaction Removal of drains small amount of clear serous drainage through the drain openings.

Oct. 8-15 No pain or fever Wounds dry Because he was scheduled for transfer I applied a plaster cuff from the hip to the ankle. This was split immediately

Oct. 17 Transfer by airplane

Oct 29 I found the patient in another hospital. He had stood the transfer well, was free from pain and looked well. The cast had been removed on Oct. 23 Several skin sutures had cut through the others were removed The wounds were closed with exception of a few small

ing 40 minutes because of the inadequacy of the hammer duration of wiring and skin suture, 15 minutes, making a total of 2 hours for the entire procedure.

Sept. 27 a.m temperature, 36.8°C pulse 80 full. Tongue coated, appearance pale, patient feels fairly well. Urinary retention. Evening temperature 37 8°C pulse 120 abdomen rigid very sensitive

Sept. 28 a.m. temperature, 36.8 C pulse 105 irregular Had vomited. Thigh pain less Evening temperature 37 4°C

Sept. 29 temperature 36.3 C pulse 78 strong Feels well, although no gas had been expelled.

Sept. 30 temperature 37.5°C pulse 100 Gas expelled and bowels evacuated by enema.

Oct. 1 pulse strong 98 Feels well slept well. Drain removed. All wounds dry without inflammatory reaction

Oct. 2–6 Feels well temperature not elevated pulse strong No pain.

Oct. 7 Change of dressings. Leg not swollen not red and not tender anywhere. A piece of necrotic fascia removed from the gunshot opening No suppuration Cloudy serous drainage through the drain opening

Oct. 9 No pain or temperature Wounds reactionless. Considerable serous secretion from the wound above the knee therefore a new drain inserted through the previous opening

Oct. 15 General condition good No discomfort from leg or abdomen Slight serous secretion. Since the patient was scheduled for transportation I applied a plaster cuff from the hip to the ankle for the immobilization of the wounds, and split it immediately

Oct. 17 Transferred by airplane.

On Oct 29 I saw the patient again in another field hospital and heard that he had suffered no ill effects from the transfer An X-ray picture taken on Oct. 20 showed good position. On Oct. 22 a temperature developed up to 39°C On Oct. 23 the cast was removed On the abdomen a small bowel fistula had formed. Fever lasted until Oct. 26 and then subsided after pus discharged from the femur wound. As the wounds on the femur and at the nailing site were still discharging pus on Oct 29 I had a hip spica applied. An X-ray picture taken previously showed extensive periosteal appositions the wire broken and the fragments overlapping 5 mm. No angulation.

Nov 10 Comfortable without fever Transfer by train

Nov 19 The transportation lasted 9 days and he stood it very well Abdominal wound almost dry *Slight drainage through the drain more drainage at the nailing site*

Nov 30 Transfer to Vienna, where he arrived without pain on Dec. 3 After removal of the cast he showed an abdominal fistula with slight secretion The femur was thickened but not inflamed and not tender to pressure Three cm. above the tip of the greater trochanter there was a fresh scar 2 x 1½ cm. in size with a small sinus from which a small amount of pus discharged on pressure In the middle of the femur there was a scar 9 x 1 cm. in size with a granulating area of 2 cm. On the outer side above the knee was a 30 cm. scar with a sinus opening 2 x 1.5 cm. Another sinus opening was present on the flexor surface. The wound on the lower leg was almost closed Peroneal palsy was still present. A small amount of pus discharged from the sinuses upon pressure The leg was 2 cm shorter X-ray pictures showed extensive periosteal appositions. The point of the nail was only 3 cm. removed from the knee joint, showing that it had penetrated for 2 more cm into the distal fragments The torn wire loop was lying obliquely (Figs. 675 676) The leg was placed on a Braun frame

Dec. 25 Temperature 37.8°C Copious discharge of thin bowel contents through the intestinal fistula. Extensive suppuration from all three sinuses on the thigh

Jan. 14 1943 Only slight suppuration General appearance very good X-ray pictures show extensive periosteal apposition (Figs. 675 676) as in Figs. 295 and 297 Fracture clinically firm. Gets up Knee 170–155°

March 27 Removal of nail, which was easily accomplished

June 2 Walks well without cane Shortening 2 cm Slight secretion from a sinus on the outer side of the femur All other wounds on the leg and on the abdomen have healed. Toe motions almost entirely free, but extension weak Right ankle joint 80–110° against 75–120° of the left.

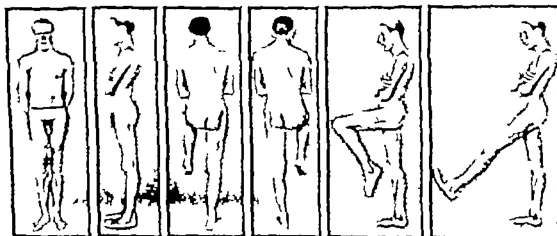


Fig. 661 Fig. 662 Fig. 663 Fig. 664

February 5 1943 May 20 1943

Figs. 661 662. Same as Figs. 657–660, after 4 months. Fracture consolidated in good position wounds closed.

Figs. 663 664 Same as Figs. 657–660 after removal of the nail and 7 months after the injury Fracture healed in excellent position Bony consolidation.



Figs. 665–670

May 22, 1943

Figs. 665–670. Same as Figs. 657–664 7 months after injury Knee 180–50° against 180–40 on the right All other joints show free active motion. Muscles strong no discomforts. The large scars anteriorly and postero-laterally are plainly visible.

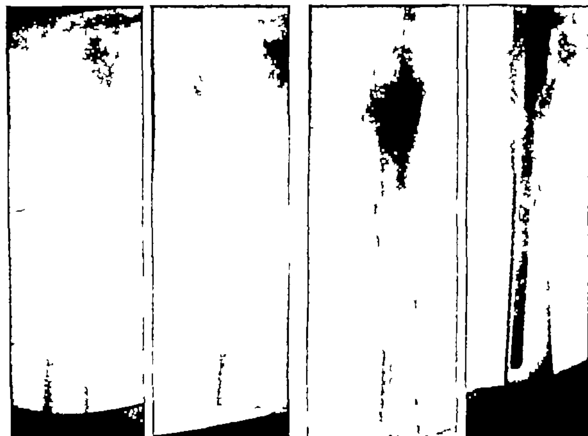


Fig. 657 Fig. 658 Fig. 659 Fig. 660

October 4 1942 October 4 1942

Figs. 657 658. Gunshot fracture of the femur with a 12 cm. butterfly fragment. The 20-year-old painter was injured by a rifle bullet. After 15 hours, wound excision, medullary nailing, 2 rubber drains, skin sutures, Braun splint.

Figs. 659 660 Same as Figs. 657 and 658, after medullary nailing. Fragments in accurate apposition. Healing without wound disturbances. Temperature 37–38° C. during the first 3 days. Drains removed after 3 days.

superficially granulating areas. One could raise and move the leg without causing the slightest pain

Nov 3 Transfer by train without external fixation, with the patient in good general condition

Nov. 11 The patient stood the 8-day trip transfer without discomfort.

Nov. 18 Transfer to Vienna where he arrived safely on Nov 20 No swelling of the thigh A superficial granulating area of 6 x 2 cm. was present in the anterior operating scar and a similar area 3 x 2 cm. in the larger posterior scar Above the greater trochanter there was a slightly secreting granulating area, 1 x 1 cm. Toes and ankle joints showed free active motion. Knee 180–145° Hip showed active flexion to 120° and free passive movement. X-ray pictures showed unchanged good position.

Nov 25 Started exercises on the knee exerciser (Figs. II/1574 1575)

Dec. 2 Gets up and walks with 2 canes. Knee 180–120°

Jan. 2 1943 Knee 180–115°

Feb. 5 All wounds epithelialized. Knee 180–110° Fracture shows bony consolidation (Figs. 661 662) Never received massage or passive motion.

Apr 13 Knee 180–55°

Case 3 On Aug 8 1942 a 29 year old man suffered a fracture of the left femur with a large wound from a shell fragment He was provided with a plaster splint from the sole of the foot to the middle of the thigh Subsequent X rays showed a comminuted fracture 8 cm in length between the middle and the proximal third similar to the case shown in Fig 322

Aug 10 Cast from foot to umbilicus was applied in a field hospital

Aug 12 New cast from tips of toes to nipple line

Aug 14 Transfer by train to a station hospital

Aug 15 Since the cast was broken pin traction with 7 Kg was applied to the tibial tuberosity

Aug. 29 Temperature 39 6 C Incision of the thigh

Sept. 7 Medullary nailing The nailing wound was closed with one suture Leg placed on a Braun frame

Sept. 11 High fever Marked suppuration Additional incision

Sept. 14 Opening of an abscess

Sept. 17 Bleeding from the profunda femoris artery which was ligated Blood transfusion

Sept. 18–Oct 11 Only slight temperature rises Good general condition

Oct. 12 Temperature 39 4 C

Oct. 16 Swelling in gluteal region Incisions at nailing site

Oct. 18 Removal of sequestra

Nov 2 For the anticipated further transportation the leg with the Braun splint was fastened to a board with plaster of paris bandages

Nov 9 Temperature again 39°C Therefore removal of board and cast

Nov 10 Leg fastened to Braun splint by bandaging In this way he was transported

Nov 14 Stood the 4-day transfer very well Leg remained on Braun frame

Dec. 2 With this splint he was further transferred to our hospital

Dec. 5 Again this transfer was borne well On the thigh and in the gluteal region there were numerous scars and 3 sinuses freely discharging pus Shortening 4 cm. Only slight motion of toes Ankle and subastragalar joint limited to one half Toes and ankle cannot be dorsiflexed actively Knee 165–120 Hip still immovable X rays showed a comminuted fracture in the proximal third healed without angulation.

Dec. 9 Extraction of the nail

Dec. 10–14 Temperature over 39°C Marked suppuration. Later afebrile

Jan 4 1943 Began to walk

Mar 15 Wounds closed except for small sinuses Walked well with a cane

Case 4 A 34-year-old man was wounded on April 27 1943 suffering a gunshot fracture of the femur with slight comminution between the middle and proximal third He was admitted to a field hospital on May 3 and was nailed immediately The condition of the wounds is not recorded The only facts mentioned were that the nailing was followed by suture of the fascia and the skin and by suppuration of the fracture hematoma. The temperature curves show elevation between 38–39 C until May 21 From May 22 to June 21 the temperature was never above 37 5°C

June 20 Application of a hip spica.

June 21 Transfer by airplane to Vienna which was borne without discomfort. Cast removed and leg placed on a Braun frame

The leg showed no swelling after removal of the cast. On the antero-lateral aspect of the upper third of the femur there was a wound 18 x 5 cm and over the greater trochanter another of 6 x 2 cm covered with fresh granulations and showing slight purulent secretion Between these two wounds there was a skin bridge of 2 cm. Paralysis of the peroneal nerve X rays showed a transverse fracture between proximal and middle third with two splinters on the medial side 25 and 30 mm. long and 8–10 mm wide Varus angulation of 12°

May 20 Extraction of nail X-ray pictures show bony union in good position (Figs 663 664)

May 25 Knee 180–50° as compared with 180–40° on the right side All other joints show free active motion (Figs. 665–670) No shortening scars are freely movable no discomfort. Return to duty

Originally it was my intention to perform medullary nailing only within the first 6–8 hours after careful debridement, leaving the wounds open. However, I obtained healing without wound complications and with good motion in 12 knee gunshot injuries involving the femur, the patella, or the tibia These came under my care from 8–30 hours after injury They were treated by critical excision of the soft tissues, debridement of the bone wounds with chisel and rongeur, or removal of the patella, with complete closure of the skin after the insertion of a drain and by immobilization in a plaster cast I dared therefore to nail these 2 femoral fractures as late as 12–14 hours after injury and to close the wounds It is my impression that by the local use of sulfa compounds, primary wound closure after critical debridement may be carried out after a longer interval following the injury than is possible without this powder

The result was not satisfactory in the first case, because of a series of untoward incidents. A nail was used which was slightly too thick driving was therefore difficult. In addition to this, it was also 4 cm too short so that it did not provide sufficient fixation therefore a wire suture was applied This was too weak and consequently broke 4 weeks later when the cast was removed Two wire sutures should have been applied The entry wound which was 1.5 cm in diameter after excision was not sutured but remained open Hence a loose piece of fascia separated which led to late infection Instead of a hip spica, only a circular cast was applied for the transfer Even this was removed too soon, so that the wire broke. After application of a hip spica, the infection subsided

In the first case if a nail of sufficient length had been used and if the fragments had been immobilized with 2 additional wire sutures and if the wound had been completely closed primary healing would probably have taken place and a hip spica would not have been necessary

In this case the advantages of the medullary nail were that the patient was at all times free from pain and that no angulation developed

In the second case complete success was achieved. The wounds healed without complications except for a few superficial granulations The patient was entirely free from pain from the first day on The slight initial temperature elevation from 37 3–38.2°C disappeared after the third day He needed no plaster cast for the prolonged transportation The functional result was excellent.

This proves that under favorable circumstances and in selected cases, open medullary nailing may be crowned with success even in the field An X ray apparatus and sufficient time are however prerequisites With a great influx of casualties, medullary nailing with painstaking excision of the wounds and closure of the skin is too time-consuming

In addition to these two cases I had the opportunity to observe 4 patients who had been operated upon by other physicians

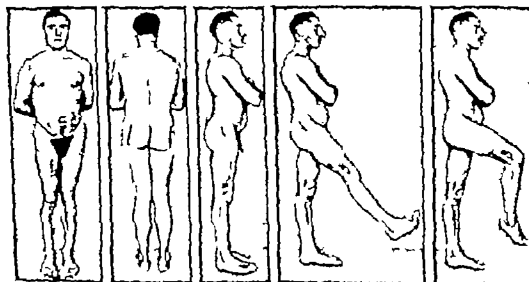


Fig. 675 Fig. 676 Fig. 677 Fig. 678

January 14 1943 May 2, 1943

Figs. 675 676. Same as Figs. 671–674 after 3½ months. Bony union in good position Extensive periosteal appositions (irritation callus due to suppuration and slight play at fracture site) Wire suture broken marked decalcification.

Figs. 677 678. Same as Figs. 671–674 after 7 months and 3 months after the extraction of the nail Bony consolidation, calcium content increased.



Figs. 679–683

June 2, 1944

Figs. 679–683 Same as Figs. 671–674 after 20 months. Shortening 2 cm. No active extension of the great toe Full active motion in the other toes, in foot joints and in hip Knee 180–110° against 180–40° on the left. Capable of sustained walking without discomfort.



Fig. 671 Fig. 672 Fig. 673 Fig. 674

September 26, 1942 September 26, 1942

Figs. 671 672. Spiral fracture of the distal third of the femur caused by shell fragment, in a 21 year-old farmer In addition, gunshot injury of abdomen with injury to small intestine, shell fragments in soft tissues of thigh and lower leg with peroneal paralysis, and gunshot in right metacarpal region. After 11 hours, operation for abdominal injury with suture of 3 wounds in the small intestine. Excision of all wounds, medullary nailing with additional wire suture, drain, skin closure, Braun splint.

Figs. 673 674. Same as Figs. 671 and 672, after nailing and wire suture. Good position. The nail is too short.

Afebrile until August 21 Wounds almost closed.

Aug 22 Temperature 38.5°C Redness and swelling at fracture site.

Aug. 24 Opening of an abscess followed by a drop in temperature.

Sept. 10 No pain or fever Lower wound clean and much smaller upper wound closed Toes cannot be extended. Fracture shows good position and good callus formation. The two splinters are lying within the callus as sequestra.

Oct. 8 Knee exercises started.

Dec. 3 Temperature 38.5 Marked redness tense swelling and pain on the flexor side of the thigh.

Dec. 6 An abscess broke through the old scar Whereupon again afebrile.

Jan. 12, 1944 X-ray pictures showed bony consolidation of the fracture. Two small sequestra lying in a cavity on the medial side. Marked periosteal appositions over the entire bone down to near the knee. Extraction of the nail, which was loose and removal of the sequestra. This was rather difficult because they were located on the medial side of the bone. A posterior incision 20 cm. in length was made. The edges of the walnut-sized cavity were flattened with a chisel. Thereupon, marked suppuration appeared.

Feb 3 Wounds smaller slight suppuration. Patient gets up

March 15 Toes now show active extension.

June 2 Wounds almost closed. Ankle and tarsal joints free. Knee 160–120° as compared with 180–45° on the right side Hip motion 180–105° only a few degrees of rotation and abduction from the mid-position. Varus 12° shortening 1 cm. Sequestra cavity much smaller

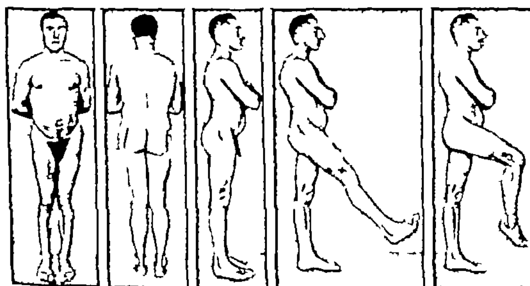


Fig 675 Fig. 676 Fig 677 Fig 678

January 14 1943 May 2, 1943

Figs. 675 676. Same as Figs. 671–674 after 3½ months. Bony union in good position. Extensive periosteal appositions (irritation callus due to suppuration and slight play at fracture site) Wire suture broken marked decalcification.

Figs. 677 678 Same as Figs. 671–674 after 7 months and 3 months after the extraction of the nail. Bony consolidation calcium content increased.



Figs. 679-683

June 2 1944

Figs. 679–683 Same as Figs. 671–674 after 20 months. Shortening 2 cm. No active extension of the great toe. Full active motion in the other toes, in foot joints and in hip. Knee 180–110° against 180–40° on the left. Capable of sustained walking without discomfort.

Case 5 A 39 year-old man was wounded on the right side and buttocks on June 11 1943 by bomb fragments and suffered a fracture of the femur He was admitted to a field hospital one hour later From the history it appeared that the wound perforated the lower third of the right thigh The exit wound on the outer side was 15 x 2 cm Over the greater trochanter was another wound 14 x 4 cm X-rays showed a butterfly fracture with a 15 cm zone of splintering between the middle and lower third The splintering started 12 cm. above the knee joint. Both wounds were excised and sulfa powder sprinkled into them The guide pin was then pushed through the proximal fragment and the nail driven in over it. The wounds remained open and were dressed with a compression bandage The leg was placed on a Braun frame X rays after nailing show the tip of the nail 7 cm removed from the knee joint

The temperature varied within normal during the first 4 days and fluctuated in the subsequent 6 days between 37 5–38 4°C

On June 20th there was no suppuration and a hip spica was applied for transportation

June 21 Transfer by airplane to Vienna without ill effects. Findings after removal of the cast A deep wound 15 x 8 cm on the outer side of the lower half of the right thigh and another 14 x 8 cm over the greater trochanter The wounds are clean the surrounding tissues not inflamed

The leg was again placed on a Braun frame.

From June 22–29 Evening temperature rises between 37.8–38.8°C.

June 29 The leg shows a varus bowing and recurvation Therefore a correction of the angulations was made and a hip spica applied which was fenestrated over the large wound Thereupon the temperature dropped.

July 18 Continues afebrile Wounds filling in suppuration slight.

Aug 9 Wounds about one-half original size.

Aug 24 Wounds almost healed cast removed fracture shows bony consolidation in good position Knee exercise started (Figs. II/1574 1575)

Sept. 10 Wounds closed Toe and ankle joints free Knee 180–90° as compared with 180–50° on the left side Hip 50 per cent free Shortening 6 cm. X ray pictures show good alignment in both planes and good callus formation. Walks with 2 canes.

Jan 6 1944 Walks with one cane.

April 3 Extraction of the nail, which was easily accomplished

May 5 Wounds well healed did not break open any more Toe and ankle joints free Knee 180–70° against 180–50° on the left. X ray pictures show good callus formation and good alignment No periosteal appositions Shortening 6 cm. Walks with elevated shoe negligible limp with endurance

Case 6 A 23-year-old man was injured by a rifle bullet on the left thigh on Nov 9 1943 at 8 00 a.m was admitted at 3 00 p.m. and immediately operated upon The patient brought his case record with him, which revealed the following

Entry wound on outer side of bullet size ragged exit wound 10 x 5 cm General condition fair markedly exsanguinated Therefore 1 000 cc. isotonic solution of blood serum salts circulatory stimulants and sulfapyridine injections. Returned to heated operating room and subcutaneous infusion of 1 000 cc. of saline solution given Recovery after half hour Ether anesthesia. Excision of both wounds and ligation of a large muscle artery close to the femoral artery Wounds irrigated with ether sulfa powder-emulsion Guide pin inserted nail driven to fracture site, fragments apposed X ray control shows excellent position on the antero-posterior view but the nail reached only to the beginning of the condyles The fracture was not firm, however therefore the nail was driven in further X ray picture shows recurvation of 5° and nail protruding 2 mm. into the joint. The attempt to retract the nail was unsuccessful because a suitable extraction instrument was lacking and the head of the nail was buried in the trochanter Therefore the trochanter was exposed by a long incision and access gained to the eye of the nail

by chiseling away the bone An attempt to extract the nail with a single pronged bone hook was equally unsuccessful because the nail was lodged too tightly Both wounds were closed with muscle and skin sutures The wound in the trochanter was left open and bandaged after sulfa powder was dusted into it No hip spica but a Volkmann splint was applied

Nov 11 1943 10 30 a m The excised and sutured wounds show primary healing Slight effusion in the knee Wound over trochanter shows no inflammatory reaction

Nov 23 3 45 p m Redressing Left knee swollen aspiration reveals clear yellow fluid an indication of irritation of the knee joint by the nail Left lower leg swollen Entry and exit wounds show primary healing

Dec 9 Subfebrile temperatures Slight secretion from the wound Purulent secretion from the wound on the medial side of the thigh General condition good Hip spica applied transferred by rail and plane

Dec. 13 Admitted to our hospital Comparatively good general condition Wears a hip spica with large windows over the trochanter and on the outer and inner sides above the knee The wound over the greater trochanter is 14 x 5 cm in size and shows slight secretion and healthy granulations The wound on the outer side is 9 x 5 cm. almost dry The wound on the inner side is 18 cm long 7 cm. wide and 3 cm deep with profuse suppuration Toes show good circulation and free motion X ray pictures show a fracture of the femur 12 cm. above the knee with a splinter 13 cm. long on the lateral side

Dec. 30 Sudden rise of temperature to 39° C with pain in all wounds radiating to the knee joint. Profuse suppuration from all 3 wounds. Necrotic fascia separates from the medial side

Jan 6 1944 Marked swelling of the wounds Fever continues

Jan 17 Less swelling temperature only 38 C

Feb 17 No fever slight suppuration, wounds smaller no pain

March 29 Slight suppuration Granulation still partly hyaline Slight callus formation.

April 27 Wound at nailing site healed

April 30 Wound at nailing site breaks open suppurates profusely

June 2 Cast removed. Entire leg enlarged no angulation At nailing site a scar 14 x 5 cm. with a 6 x 2 cm. area of hyaline granulations Lower lateral wound closed scar 9 x 5 cm Lower medial wound 4 x 1 cm. with hyaline granulations profusely suppurating within a scar of 18 x 7 cm. No effusion in the knee joint, patella slightly movable. Subtalar joint immovable talocrural joint 95–105 against 70–145° on the right, knee 175° immobile against 180–60 on the right Hip 180–145° Rotation and abduction almost nil Shortening 2 cm. X rays show bony union in good position Negligible periosteal appositions outside the fracture site

June 5 Removal of the nail easily accomplished

June 10 After removal of the nail, no disturbances in the knee joint. Swelling of the leg markedly reduced wounds smaller Mobility increased

In the first edition I wrote After reviewing these 5 case histories, I believe that I can recommend open medullary nailing in the field for strictly selected, fresh gunshot fractures of the femur, provided the circumstances as to location and personnel are particularly favorable '

Since then I have continued the observation of the first 5 cases for another year and a sixth case was added I must now say that great caution must be exercised because the dangers of open medullary nailing and the number of possible incidents are too great In cases 1 and 3 nails were used which were too short. Therefore marked angulation and finally a shortening of 6 cm developed in case 3 In case 6, the nail was too long and protruded 2 mm. beyond the bone From the subsequent course it appears that it did not actually enter the knee joint but stopped within the cartilage of the joint Owing to the lack of a suitable extraction tool, the retraction

of the nail was impossible In case 4 the nail was inserted too far laterally, so that a varus angulation of 12° resulted

In most of these cases the nailing did not shorten the period of treatment nor was the period of suppuration shorter than with other methods It is surprising that no osteomyelitis with medullary sequestra developed in any of these 6 cases, although marked suppuration occurred in 5 of them

A result as good as in case 2 can only be obtained if the following prerequisites are fulfilled

General requirements with regard to the patient Open medullary nailing must not be performed unless the patient is in good general condition. Heart, lungs, pulse, reflexes, joint motions and sensation must therefore be examined carefully

Local requirements with regard to the patient Best suited to nailing are transverse fractures (Figs. 490–503, 532–539, 608–617) and short oblique fractures (Figs. 540–547) above the middle Also, spiral fractures (Figs. 657–664) may be nailed Fractures below the middle may be nailed only by the well-experienced surgeon, comminuted fractures only if supplementary wire traction is possible or if a wound and bone spreader is inserted as advised by Küntscher

The wound must not be too severely torn or soiled, and must not contain many splinters and foreign bodies Nailing must be preceded by thorough removal of all foreign material.

Contra indications with regard to the patient If the general condition is poor from loss of blood, loss of body heat or prolonged transportation (weak, fast pulse, pale appearance, cold sweat), open medullary nailing must not be performed under any circumstances because it is not an emergency operation. **If the injured is in profound shock nailing must absolutely be omitted, or the outcome may be fatal**

Contra indications with regard to the wound and the bone In perforating gunshot wounds from smooth missiles, open medullary nailing must not be performed because it may lead to disturbance of the wound healing, since such wounds usually heal without complications Such cases may be suited for closed medullary nailing Extensively comminuted fractures and transverse and oblique fractures near the joints must not be nailed because the nail does not provide sufficient stability

Requirements on the part of the surgeon He must have had sufficient experience with medullary nailing under peace time conditions and be familiar with the possible complications.

Requirements as to instruments and equipment An X ray apparatus is essential. Unless X ray pictures of sufficient size are taken neither the type of fracture nor the length and width of the medullary canal can be determined A sufficient number of nails of various lengths and thicknesses must be available and a hammer of at least 0.5 Kg weight, as well as all the instruments listed on pages 22–26 No reduction apparatus is needed

Requirements as to local conditions Facilities for aseptic technique as well as facilities for one to two weeks of continued observation are required.

Time of operation The best time for nailing is within the first 6–8 hours In

cases 1 and 2, I performed the operation after 12-14 hours, if infection had been already evident, I should not have dared to undertake the operation

The length, width and curve of the medullary canal are determined in the manner described on page 40

Anesthesia Local anesthesia is preferable for the debridement For the driving of the nail general anesthesia is usually required

Protection against heat loss (see page 169) must again be emphasized

Wound excision Thorough excision of the wound with the removal of even the smallest torn muscle fibers (see pages I/106-130), which will require at least one hour can be undertaken only if the influx of wounded is small Otherwise, only the grossly torn muscles and all foreign material are excised The skin incisions must be of sufficient length to reach, in particular, the peripheral muscle stumps where severe infection is most likely to arise, if they have retracted and escaped observation through small incisions

The insertion of drains into the deepest parts of the wound must not be omitted Sprinkling of sulfa powder into the wounds has proven of value With its use the wounds usually show a fresh red appearance and suppuration is held to a minimum Only a thin layer should be applied, otherwise, clumps form which may cause retention of pus Repeated applications irritate the wound and should therefore be omitted.

Open nailing If the general condition is good after thorough debridement of the wounds the guide pin and nail are inserted as described on page 190, 191 If the medullary cavity was accurately measured and if a nail which is not too thick has been used the operation consumes less time than the application of a plaster cast or of a splint

Skin suture as carried out in cases 1 and 2, is permissible only with extensive experience and if the excision of the wounds was very thorough As a rule the wound should remain wide open as in case 5 The nailing site must never be sutured. If the wounds remain clean a secondary closure may be done after 5-6 days. With the use of penicillin, medullary nailing may perhaps be safely performed more frequently

Post-operative positioning Placing the leg on a Braun frame usually relieves the patient of pain

Transportation If the patient has to be moved within the first 3 weeks a hip spica serves best After 3 weeks transportation with the leg tied to a Braun frame is sufficient

Opening of abscesses If the wounds are left open and rubber drains are inserted into the deepest parts no abscesses develop as a rule (see case 5) Otherwise, they must be opened in the usual manner at the most dependent site

Open Medullary Nailing of Infected Gunshot Fractures of the Femur

Cases 3 and 4 of the previous section show that infected gunshot fractures may be nailed In case 3 a serious error was made in closing the nailing site by a suture. This causes a cellulitis in the gluteal region which can be prevented by leaving the

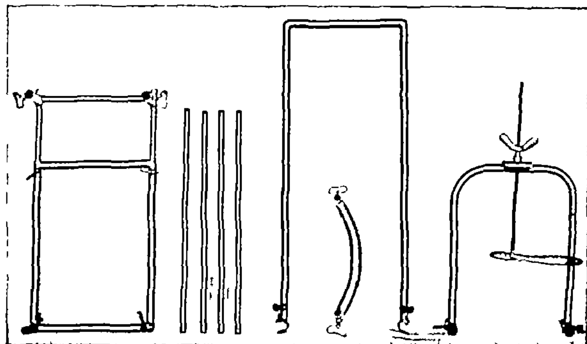


Fig 684

Fig 684 Screw traction apparatus disassembled. The attachable frame is used for stabilizing the limb as shown in Fig. 527 The apparatus weighs 12.5 Kg and can be packed into a carrying case 25 x 45 x 85 cm The attachment shown in Fig I/73 which weighs 6.7 kg and for which there is room in the case permits the application of a hip spica without assistance (Figs. 57a b E I/74 I/75 and II/1626)

nailing site open as a matter of routine. The operations repeated at short intervals between September 10 and October 18 indicate that the pus collections were never sufficiently exposed

In case 4 an abscess formed because for some unintelligible reason the skin and fascia were sutured in the presence of suppuration. After removal of the sutures, the wounds healed satisfactorily

It is interesting to note that in neither of these cases did osteomyelitis develop although pus was carried into the medullary cavity by the nail

Ehrlich and Häbler reported satisfactory initial results in infected fractures In spite of this I cannot decide in its favor although it offers the advantages of good immobilization of the fragments combined with free access to the wound These cases must be observed for additional years or decades in order to determine whether late osteomyelitic foci develop subsequently

Closed Medullary Nailing of Gunshot Fractures of the Femur

Heim in 'Der Chirurg No 13 1943 recommended closed nailing of gunshot fractures of the femur He reported excellent results in 5 cases.

He did not perform the nailing immediately but later when the patient was afebrile He listed the following four requirements

1 Gunshot fractures of the femur suited for nailing are routinely immobilized (wire extension) after operative wound toilet.

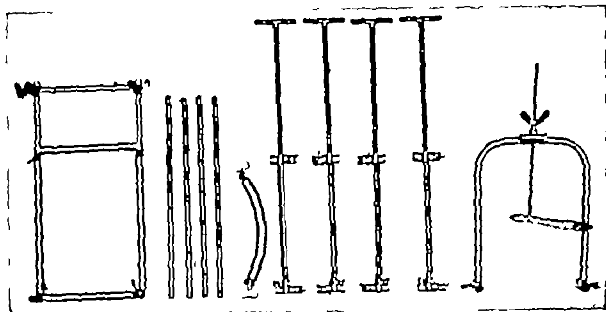


Fig 685

Fig. 685 Screw traction apparatus of Fig 528 disassembled The 4 rotating bars are used for securing the limb. The apparatus weighs 13.5 kg and can be accommodated in a carrying case 25 x 45 x 85 cm.

2 Nailing must be performed in the afebrile stage
3 The nailing must not be carried out from the wound
"4 The prophylactic administration of sulfa drugs must precede the operation "

He demands favorable external circumstances such as were available in the base hospitals of the west a good general condition of the patient and favorable local wound conditions. He operates only on fractures caused by *small-calibre smooth* bullets or by small shell fragments and secondary fragments, never on those caused by artillery or explosions. Most of the wounded were admitted after 2 hours.

About the treatment of the wounds, he writes

'Our procedure was to administer immediately upon admission an infusion and transfusion in combination with an injectable sulfa drug intravenously before surgical treatment and to apply a thick layer of sulfa powder after the treatment of the wound This was followed by 4 days of sulfa administration in the usual manner

By this procedure temperature elevations disappeared within the first to third week in the 5 cases that were subsequently nailed Concurrently the *general condition* sleep and appetite improved and the leukocyte count returned to normal *within this period* The mild course of the infection was furthermore evident from the low percentage of lymphocytes which were never below 20% The wounds showed satisfactory healing with moderate *secretion*

After 3–4 afebrile days a second prophylactic course of sulfa injections was started and on the 4th day of this course the nailing was performed after a satisfactory sulfanilimide blood level had been obtained It is an open question whether *the initial sulfanilimide* treatment or the prophylactic second sulfanilimide course played the more *important* part in keeping the infection to a low grade type I must say however that the sulfa courses provide a certain feeling of safety

It is regrettable that the author did not report the *size* of the wounds and the extent in surface and depth of the wound excision Since he treated only casualties caused by smooth bullets and small shell *fragments* the wounds were probably small

The closed nailing was performed in the usual manner under traction but without reduction apparatus.

He writes further

The results with the medullary nailing of gunshot fractures of the femur performed to date are entirely satisfactory Reactive temperature rises following the nailing were strikingly slight and lasted only a few days The blood picture showed no changes. No flare-up of soft tissue infection was ever observed On the contrary wounds showed a better healing tendency after nailing Infection of the bone marrow never occurred nor any infection of lymph vessels or lymph glands. Sequestra were not demonstrable either clinically or roentgenologically Decalcification or mottled atrophy has not appeared in the X ray pictures to date

Transverse fractures were able to get up 1–4 weeks after operation comminuted fractures were laid up for 6–8 weeks. After 3–6 weeks motion was free in all joints. Any after treatment was therefore superfluous As soon as the patients were able to get about without difficulty they were furloughed home for 6–8 weeks Then the nail was extracted and 1–2 weeks later they were sent back to duty

An excerpt from the case histories follows

Case 1 A. W F Gunshot fracture of the femur by 2 cm. bullet (Spitfire) during flight. Admission 2 hours after injury Moderate shock from injury and transportation. After admission immediately tetanus antitoxin sulfa drug intravenously and infusion of isotonic solution of blood serum salts followed by wound toilet a half hour later Wire extension Course of sulfa drugs for 4 days Afebrile on the eighth day Slight secretion. Then a second prophylactic course of sulfa was given On the fifth day medullary nailing and removal of wire traction. Temperature reaction up to 37 5 for 2 days then continuously afebrile. Wound healed rapidly Free motion of all joints 21 days after nailing Walked on the 24th day after nailing (without cane) Wound healed After another 28 days furloughed home for 8 weeks. On return the nail was extracted. After another 21 days, sent back to duty No after treatment required.

Case 2 G W Gunshot fracture of the femur from 2 cm. bullet (Night Bomber) in flight. Admission one and a half hours later Moderate shock from trauma and transportation. Preliminary treatment as in case 1 Afebrile on the 14th day After second course of sulfa drugs nailing on the fifth day following subsidence of temperature The reaction to nailing consisted in temperature rises between 37° and 38° for four days followed by continuous afebrility Wound healed rapidly Got up 14 days after nailing (without cane) Free motion of joints after 4 weeks. After six weeks furloughed home for eight weeks. Upon return, the nail was extracted. Shortening of 1½ cm. compensated by raising the sole of the shoe. A few days later fit for duty No after treatment required

Cases 3 and 4 are similar to cases 1 and 2

Case 5 A. K Bilateral gunshot fracture of the femur (right, smooth transverse fracture left, comminuted fracture) Humerus gunshot fracture on the right side and gunshot fracture of the mandible during a sea-battle. Admission 7½ hours after injury Upon admission, profound shock from trauma and transportation Marked loss of blood pulse hardly palpable Immediately upon admission blood transfusion of 550 cc. isotonic solution of blood serum salts 1500 cc. with sympathico-mimetic drugs, 500 cc of physiol saline with sulfa drugs i.v and tetanus antitoxin. Good recovery after 45 minutes. Operative wound toilet (narcotics i.m and local anesthesia) and wire traction on both legs. Course of sulfa drug started. Slight wound infection, temperature between 37° and 38° for 18 days. General condition recovering slowly On the 20th day second

prophylactic sulfa course on the 25th day nailing of both femora at one sitting (duration 43 minutes) Removal of traction wires. Slight general reaction No temperature elevations on the first and second days, elevations between 37.1 and 38.2 from the third to the seventh day after nailing Then continuously afebrile After 14 days cautious moving of the joints in bed Wounds healing well. Strikingly rapid improvement of the general condition Because the fracture on the left side was comminuted he was not allowed out of bed for eight weeks after nailing Walking exercises started with two canes. After another 5 weeks walking was possible without canes and motions at the hip knee and foot joints were entirely free X rays showed no signs of decalcification The nail on the side of the transverse fracture was then extracted but on the comminuted side it was left Furloughed home (traveled unaccompanied) Upon return gait and stair-climbing were unimpeded Second nail extracted Deep knee bend was possible without difficulty Abduction not restricted 2 cm shortening on the left side Slight limp compensated by raise of the shoe sole No after treatment required (Humerus and mandibular fractures healed at the same time with good function.)

Heim also says

"Although the experience with medullary nailing of femoral gunshot fractures is based upon a relatively small number of cases I feel that in view of the excellent functional results it should not be rejected in principle The question must not be generalized Should gunshot fractures of the femur be nailed or not? but Are there femoral gunshot fractures which may be nailed?

"With critical selection with consideration of outside factors and correct indications according to general principles of surgery, it will crystallize that quite a number of femoral gunshot fractures could safely be nailed The advantages of nailing are so convincing that we should give our wounded fellowmen the benefit of it even if only in a small number of selected cases. Although personally I am convinced that the indication for nailing of femoral gunshot fractures will gradually be expanded an indiscriminate unsystematic nailing on the other hand does more harm than good and in the long run will interfere with the evolution of this method and may even unjustifiably discredit it"

Heim's results are so convincing that this procedure must be recommended for gunshot fractures with small wounds, provided the requirements given on page 164 are met. Closed nailing is greatly facilitated by the use of such a reduction apparatus as shown in Figs. 684 and 685 This can easily be carried in a suitcase 25 x 45 x 85 cm If, in addition the attachment shown in Figure I/73, weighing 7 Kg and easily accommodated in the same suitcase is available, any hip spica can be applied without assistance (Figs 57a, b E, I/74, I/75 and II/1626)

Gunshot fractures of the femur in which the wounds heal aseptically without excision, are still better suited for closed nailing They are best treated at first by wire or pin traction to prevent shortening and angulation

After they have been afebrile for 2 weeks, the operation may be performed with negligible danger

Open medullary nailing should be considered only in those cases in which the wounds are so large that the fragments are exposed during debridement

Open Medullary Nailing of Old Femoral Fractures

Any adult, with a femoral fracture healed with a shortening of more than 3 cm, with angulation of more than 15° or with a rotatory displacement will limp and develop late disturbances in the knee and hip joint These deformities should therefore



Fig 686 Fig 687 Fig. 688 Fig 689

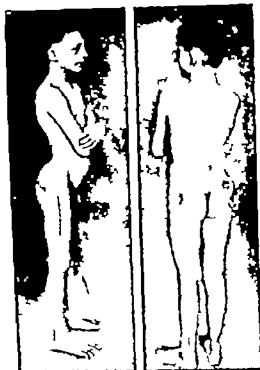
October 27 1941 February 20 1942

Figs. 686, 687 A 4-weeks-old fracture of the right femur with 30° varus and 20° antecurvation in a 9-year old boy who was knocked down by a car Fracture exposed and nailed. Got up 10 days after operation and left the hospital on the 20th day Such fractures should not be treated with a nail because of the increased danger of osteomyelitis in children. Bloodless straightening is easy With a hip spica including the chest they can usually get up and leave the hospital after 2–4 days. Such fractures are usually firm for weight bearing in 4–5 weeks and the joints usually recover full range of motion 3–4 weeks after removal of the cast unless they were irritated by massage and passive motion The lateral displacement by full width of the shaft is irrelevant cosmetically as well as functionally as shown in Figs. I/196–203 Medullary *nailing thus brings no advantages, but entails great risks.*

Figs. 688 689 Same as Figs. 686 and 687 after 4 months. Bony union in good position.

be eliminated if the general conditions and the external circumstances permit. In children such deformities if not too marked are corrected by growth With angulation patients are sometimes free from discomfort for 10–20 years then arthritic changes develop especially in the knee joint (see Böhler 'Der Chirurg' No 4 1942) Consequently I have always straightened these deformities within the first few months after the injury while the bone was still somewhat soft, with the osteoclast of Phelps-Gocht (Figs 91 E I/108) or of Schultze (Figs II/2129 2130) and continued the treatment using traction more often than a plaster cast (Figs 715–718 L II/2125–2137)

For these cases Küntscher s medullary nailing represents a particularly valuable step forward because with proper technique and correct selection no supplementary traction or plaster cast fixation is required hence the muscles and joints already impaired do not have to be subjected to further immobilization but can be exercised actively in 2–3 weeks after the wounds have healed In children open medullary nailing should not be taken into consideration because of the increased danger of



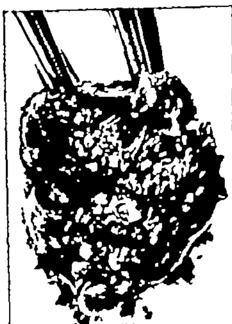


Fig 690 Fig 691 Fig 692
February 19 1942 February 20 1942

Figs. 690 691 Same as Figs 686–689 4 months after operation The nailing site bulges because the nail protrudes 5 cm from the greater trochanter After extraction of the nail, all joints show full range of active motion.

Fig. 692. The bursa which covered the head of the nail is filled with rice bodies. Size 4 x 4.5 cm.

osteomyelitis (see page 151) In old fractures with no shortening but merely angulation (Figs 693–696), straightening of the fragments followed by a plaster cast is simpler and less dangerous than medullary nailing

Nailing is never an emergency procedure Since exposure of the femur constitutes a major operation it should be performed only if good general and normal skin conditions prevail and if the shortening is no more than 4 cm Non-observance of these rules has cost many people's lives. If the skin is diseased in any way, the operation must be delayed until the skin has been normal for at least 2 months Small scars adhering to the bone must be excised The fracture must be covered with normal skin by undermining the edges. After this operation at least another two months should elapse before medullary nailing is performed

If an attempt is made to correct a shortening of more than 4 cm during the operation great force is required and much time is consumed Tissues are torn which leads to limitation of motion The sudden stretching may cause severe nerve and circulatory disturbances Since the operation is frequently a prolonged one a disturbance of the asepsis with subsequent infection of the torn tissues is more apt to occur Therefore the shortening should be eliminated before nailing

Case history Before proceeding with such a major operation as closed refracture or open osteotomy of the femur with subsequent nailing an accurate history must be obtained to determine the nature of the original injury A careful general



Fig 693 Fig 694 Fig 695 Fig 696

March 16 1942 January 27 1943

Figs. 693 694 X-ray checkup of case shown in Fig. 317 after 4½ months. The fracture healed with valgus and recurvation of 15° each (see Figs. 639 640)

Figs. 695 696. Same as Figs. 693 and 694 after 10 months. The nail has been driven in deeply enough. Bony union in good position In this fracture it would have been simpler and less dangerous to straighten the bone with the osteoclast of Phelps-Gocht (Figs. 91 E I/108 and II/2746) or of Schultze (Figs. II/2129 2130) and to apply a hip spica for 6 weeks. The backwards displacement of the distal fragment is irrel evant without functional or cosmetical significance as shown in Figs. I/206–215 and II/2016–2026.

and local examination must be made with particular attention to heart and circula tion the shortening angulation and the condition of the muscles and joints. Photographs should be taken One should not have to admit after the operation that non interference would have been preferable Good X ray pictures of sufficient length are essential. Küntscher states that the indication for operation should be put down in writing

Indications for medullary nailing of old femoral fractures

1 Shortening of more than 3 cm
2 Angulation of more than 15°
3 Rotatory displacement of more than 15°
4 Delayed callus formation expecially following excessive traction

Contra indications to medullary nailing of old femoral fractures

1 Impaired general condition All internal organs, especially circulation, must be in order

2 Age over 40 years Above this age, operation should be the exception
3 Age under 16 years entails the danger of osteomyelitis
4 Local inflammatory processes of the bone Sinuses must have been closed for at least one year
5 Abnormal skin conditions (inflammation, adherence, extensive scars)
6 Shortening of more than 4 cm This must be corrected pre-operatively by continuous traction
7 Extensive ossification of the medullary canal
8 Serious disturbances of muscles and joints

Correction of shortening by continuous traction after closed refracture Within the first 4–6 months following a fracture the callus is still soft enough to be broken with the osteoclast of Phelps-Gocht (Figs 91 I, I/108) or of Schultze (Figs II/2129, 2130) A nail or wire traction is then applied above the knee and one seventh of the body weight is used for traction (Figs II/1604–1606) After 2 days new X ray pictures must be taken Since in these cases the muscles have been shortened for months, the traction weight must be increased With a body weight of 70 Kg., a traction of 12–15 Kg is usually required In this way the shortening can usually be eliminated within a few days As soon as it has been corrected the operation may be performed If the nailing is not done but the treatment with traction continued then the weights must be reduced to prevent distraction

After the shortening is corrected or if it was less than 4 cm one may proceed with medullary nailing

Determination of the length and width of the medullary canal On X ray pictures of sufficient length the narrowest area of the medullary canal is selected and measured (Figs 1–9) The nail must always be 1–2 mm thinner than the isthmus If the bone is markedly curved the thinnest nail measuring 8 mm should be used The length is determined from the well leg with the hip and knee joints at a right angle It must be considered however, that the fractured bone may occasionally have to be nailed with a certain shortening

The instruments and apparatus enumerated on pages 22–26 must be in readiness. A reduction apparatus is not necessary nor a second X ray apparatus

Protection against heat loss Since the operation is major in character, usually causing a fall in blood pressure and marked perspiration, the well leg, the body and the arms should be warmly covered to prevent heat loss

Blood donor Dangerous shock is not uncommon Hence a donor must be on hand The blood compatibility must be determined in advance

Positioning The patient is placed on the well side because the greater trochanter cannot be reached satisfactorily in posterior recumbency

Anesthesia General or spinal anesthesia is suitable. To prevent dangerous lowering of the blood pressure, no preliminary narcotic should be given if spinal anesthesia is contemplated

Tourniquet In fractures of the middle and lower third, a strong sterile rubber hose is used as a tourniquet around the upper end of the femur, held by 2 strong



Fig 697 Fig. 698 Fig. 699 Fig 700
October 5 1942 October 13 1942

Figs. 697 698 Spiral fracture 3 months old, of the lower third of the left femur caused by rifle shot in a 36-year-old office worker Wounds aseptic. On the 3rd day wire traction was applied and continued for 6 weeks with 12 5 Kg. Then hip spica for another 6 weeks Marked decalcification of the distal end of the proximal fragment and no trace of callus formation due to excessive traction.

Figs 699 700 Same as Figs 697 and 698 after unsuccessful medullary nailing *elsewhere* The nail was driven in without previous reduction. The fracture should preferably have been exposed by open operation and united with 2 circumferential wire sutures followed by a hip spica.

clamps after sterile draping of the operative field this speeds the procedure and no blood is lost during the exposure of the bone In fractures of the upper third a Steinmann pin is inserted antero-posteriorly through the tendinous insertions at the tip of the greater trochanter Applying a sterile rubber hose above the same a bloodless field can be obtained for the upper third of the thigh as well

Exposure of the bone The bone is exposed through a lateral approach Open nailing is most simple if no or only slight callus has been formed with the original jagged shape of the fracture surfaces still preserved (Figs 686 687) They can be placed in exact apposition and then nailed If callus has formed the fracture ends have been transformed and the fracture surfaces can usually no longer be distinguished (Figs 693 694)

Guide groove In order to replace the fragments after osteotomy without rotation a helpful guide is provided by gouging a longitudinal groove about 5–6 cm long and 1 or 2 mm deep into the anterior or lateral aspect of the bone before severing it. If a rotation is present requiring correction, then the amount of corrective rotation necessary can readily be estimated by offsetting the two sections of the groove proportionately

Osteotomy The bone is severed through the old fracture line if possible. Oste



Fig 701 Fig 702 Fig. 703 Fig. 704
November 17 1942 July 1 1943

Figs. 701 702 Same as Figs 699 and 700, after 5 weeks. To correct the recurvation and varus angulation, wire traction with 10 Kg. weight was used. This caused a separation of the fragments and the nail slipped out. The nail was then removed and a hip spica applied.

Figs. 703 704 Same as Figs. 697–700 9 months after nailing and exactly one year after injury and 1 month after removal of the last plaster cast Bony union marked decalcification Knee joint entirely unstable. Toes and foot joints two-thirds restricted Walks with one cane If traction in the beginning had not been excessive, this fracture would probably have united in 6–8 weeks and limitation of motion would not have ensued.

otomy within the healthy section of the bone does not need to be considered because eburnated bones following severe infections are not suited for medullary nailing Angulations are corrected by the removal of a cuneiform section of proper size

Procedure with focal infection If a cavity filled with granulations or pus is encountered during the exposure or severance of the bone the operation must be terminated. Medullary nailing must then be delayed for 3–4 months after the closure of the wound or preferably omitted entirely

Exposure of the medullary cavity If the medullary canal is not patent after osteotomy it is opened by means of an awl In older fractures the electric round burr is needed

Removal of tourniquet The tourniquet is then removed Spouting blood vessels are clamped They usually do not have to be ligated if the clamps are left for 10 minutes

Insertion of guide pin After re-checking the fitting of guide pin and nail (see page 172) the guide pin is introduced into the proximal fragment and carried out above the greater trochanter (Figs 181 182) and a short medullary nail is driven into the greater trochanter for 1–2 cm The first guide pin is then extracted from below and a



Fig. 697 Fig 698 Fig 699 Fig 700
October 5 1942 October 13 1942

Figs. 697 698. Spiral fracture 3 months old of the lower third of the left femur caused by rifle shot in a 36-year-old office worker Wounds aseptic On the 3rd day wire traction was applied and continued for 6 weeks with 12.5 Kg Then hip spica for another 6 weeks Marked decalcification of the distal end of the proximal fragment and no trace of callus formation due to excessive traction.

Figs. 699 700 Same as Figs. 697 and 698 after unsuccessful medullary nailing *elsewhere* The nail was driven in without previous reduction. The fracture should preferably have been exposed by open operation and united with 2 circumferential wire sutures followed by a hip spica.

clamps after sterile draping of the operative field this speeds the procedure and no blood is lost during the exposure of the bone In fractures of the upper third a Steinmann pin is inserted antero-posteriorly through the tendinous insertions at the tip of the greater trochanter Applying a sterile rubber hose above the same, a bloodless field can be obtained for the upper third of the thigh as well

Exposure of the bone The bone is exposed through a lateral approach Open nailing is most simple if no or only slight callus has been formed with the original jagged shape of the fracture surfaces still preserved (Figs 686 687) They can be placed in exact apposition and then nailed If callus has formed the fracture ends have been transformed and the fracture surfaces can usually no longer be distinguished (Figs 693 694)

Guide groove In order to replace the fragments after osteotomy without rotation a helpful guide is provided by gouging a longitudinal groove about 5–6 cm long and 1 or 2 mm deep into the anterior or lateral aspect of the bone before severing it. If a rotation is present requiring correction then the amount of corrective rotation necessary can readily be estimated by offsetting the two sections of the groove proportionately

Osteotomy The bone is severed through the old fracture line if possible. Oste-

apparatus (see Figs II/1574 1575) may begin with 5–10 minutes in the morning and afternoon, gradually increasing to 1 hour On one occasion a patient with a nailed hip, contrary to this rule, exercised for an hour the first time although pain appeared towards the end The next day he had a thrombo-phlebitis and a pulmonary embolism from which he almost died

A warning must be sounded *against vigorous massage and forcible passive motion* especially if the nailing was done in a previously infected fracture, because this may lead to a flare up

Forcible manipulation under anesthesia must be omitted because it damages the knee joint A case of peroneal paralysis following such a maneuver has been reported (Stotz)

Untoward incidents during medullary nailing If the fragments are not reduced accurately and if their position after insertion of the guide pin is not checked by X ray pictures, the nail may take a false route, as shown in Figs 699–702 In this case, if the fragments had been held together with Lambotte clamps after the appearance of the tip of the pin in the medullary cavity of the proximal fragment—which would have been easy because of the long oblique fracture surfaces—the medullary nail would have penetrated into the right place of the distal fragment By additional circumferential wire sutures the fracture would have been so firm that the knee could have been exercised after 2–3 weeks Motion and calcium content would have returned to normal in a short time The nail should have been retracted at any rate The supplementary continuous traction with 10 Kg separated the fragments and caused additional damage to the joint, which in the case eventually became entirely stiff (Figs 703, 704)

Use of too short a nail If too short a nail has been used as in Figs 232–243, it may extrude and angulation may develop

Causes of Failure in Open Medullary Nailing of Old Fractures

1 **Operation when the general condition is not entirely satisfactory Medullary nailing is not an emergency measure**
2 Operation in people over 40 years of age
3 *Operation within one year after closure of sinuses in infected fractures*
4 Operation in the presence of skin pathology (inflammation, scars adhering to the bone)
5 Medullary nailing with shortening of more than 4 cm This must be eliminated first
6 Nailing if extensive bone formation is present in the medullary cavity
7 Nailing if muscles or joints are already severely damaged.
8 Operating without the necessary instrumentarium
9 Neglect to determine accurately the length, width and curve of the medullary canal
10 Neglect to check the length and thickness of the guide pin and the medullary nail and their matching
11 Omission of protection against heat loss.

second of proper length and thickness is introduced from above through the short nail into the bone until it appears at the fracture The short nail, which serves only as a temporary guide for the guide pin, is then removed.

Reduction of fragments The fracture stumps are coapted and the guide pin pushed into the distal fragment. The fragments are held and guided by Lambotte clamps (Fig 85) After the pin has penetrated deeply enough, the angulation is checked as far as this is possible within the comparatively narrow operative field. After the fragments have been aligned by means of the guide groove, they are held firm with the Lambotte clamps.

Check of pulse At times the pulse becomes very rapid during the insertion of the guide pin During the nailing, this occurs frequently If the pulse remains feeble and rapid, blood should be transfused

X-ray pictures are then taken in both planes The films must be at least 40 cm. long and the knee joint line must be visible The distance of the guide pin from the knee joint (Figs 707 708) and the distance it protrudes from the greater trochanter are measured. In this way the length of the required medullary nail can be determined very accurately This is of particular importance for all fractures below the middle, i e below the isthmus (Figs 1–11) These X ray pictures serve also as a check of the coaptation of the fragments and the angulation If the coaptation of the fracture is not satisfactory the guide pin is retracted and the fracture surfaces are reshaped by chiseling or sawing The guide pin is then reinserted and a new set of X ray pictures serves again as check To prevent delay, a rapid developer (see page 35) should be used

Driving of the nail After the angulation and rotation have been corrected, a nail of the predetermined length is driven in over the guide pin. When it approaches the fracture the fragments must be held together in the correct position using the groove as a guide

X ray control When the nail has been driven to within 2 cm of the greater trochanter new X ray pictures are made in both planes. If there is a hiatus between the fragments they are impacted by blows upon the sole of the foot or upon the flexed knee

Supplementary wire suture The stability against rotation is then checked In fractures below the middle this is frequently lacking Then both fragments are drilled transversely and united with a wire loop (Figs 709 710)

Drainage and wound closure After the nailing and wiring, a drain is inserted and brought out postero-laterally The periosteum fascia and skin are then sutured and a compression bandage is applied.

Post-operative positioning The leg is placed on a Braun frame in a firm bed (Figs 53, 70 E I/65 and I/91) The foot is suspended with a sling (Fig II/2641) or with Unna-paste or adhesive plaster traction (Figs 684 685 and 679 E II/1604–1610)

The *drain is removed* after 24–36 hours.

Functional exercises The toes and foot joints are moved actively through the full range from the first day on Knee exercises must not be started for 2–3 weeks, until the wounds show perfect healing and are entirely dry Then knee exercising with



Fig 709 Fig 710 Fig 711 Fig 712
June 4 1943 October 29 1943

Figs. 709 710 Same as Figs. 705–708 after driving of the nail and longitudinal wire suture to prevent rotation. Good alignment in both views.

Figs. 711 712. Same as Figs 709 and 710 after 5 months, showing bony union in good position.

26 Premature knee exercises, i e before 2 weeks and before the wounds are completely healed
27 Vigorous massage and forcible passive motion
28 Manipulation of the knee under general anesthesia

Open Medullary Nailing of Mal united Femoral Fractures

A fracture of the femur healed with a shortening of more than 3 cm with an angulation of more than 15 cm or with a rotatory displacement of more than 10–15° usually causes a limp and disturbances will develop later in the knee and hip joints occasionally also in the talo-crural and subastragalar joints of the injured leg With marked shortening, even the joints of the well leg and of the spine may be involved. These malpositions should therefore be corrected if the general condi tion and external circumstances permit

Angulation without shortening leaves the patient without discomfort possibly for ten to twenty years and only then may arthrotic changes, especially in the knee joints develop (see Böhler Der Chirurg No 4 1942) For this reason I have always tried to correct these displacements If the fragments had united with consolidated callus I did an open oblique osteotomy followed by continuous traction or in some cases after correction of the shortening a plaster cast was used (Figs II/2138–2150) I have rarely used osteosynthesis with wire plates and screws because they never offer sufficient stability without a supplementary plaster cast whereas with proper technique and accurate indication Küntscher s medullary nail unites the fragments immovably



Fig. 705 Fig. 706 Fig. 707 Fig. 708
May 18 1943 June 4 1943

Figs. 705 706. A 5-months-old gunshot fracture of the femur healed with 15° varus and a shortening of 8 cm. Rifle shot injury in a 22-year-old man Was given a hip spica for 8 weeks, whereupon the fracture showed bony union. Muscles strong (see Fig. 723) No decalcification. Knee 180-70° all other joints actively free.

Figs. 707 708. Same as Figs. 705 and 706, after transverse freshening of both fragments and removal of a wedge and after the insertion of the measuring pin. This reaches to the joint cartilage.

12 Operation in supine recumbency instead of lateral recumbency The trochanter is not satisfactorily accessible
13 Omission of tourniquet
14 *Failure to have a blood donor in readiness*
15 Failure to make a guide groove before osteotomy to prevent rotational misalignment
16 Failure to remove a wedge for the correction of angulation
17 Nailing if a focus of granulations or pus is found during exposure or osteotomy of the bone
18 Neglect of hemostasis before the introduction of the guide pin
19 Neglect to measure accurately the length of the second guide pin
20 Neglect to check by X ray pictures the position of the guide pin in the distal fragment after its insertion
21 Neglect to measure accurately the length of the medullary nail
22 Failure to check the position of the nail by X ray pictures
23 Omission of supplementary wire sutures if the fragments can still be rotated against each other
24 Neglect to insert a drain
25 Leaving the drain in situ for more than 48 hours if there is no rise in temperature



Fig. 715
November 11 1943

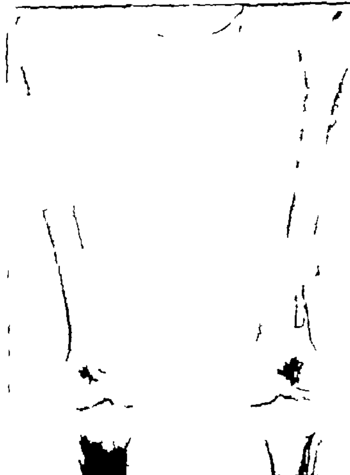


Fig 716
May 20 1944

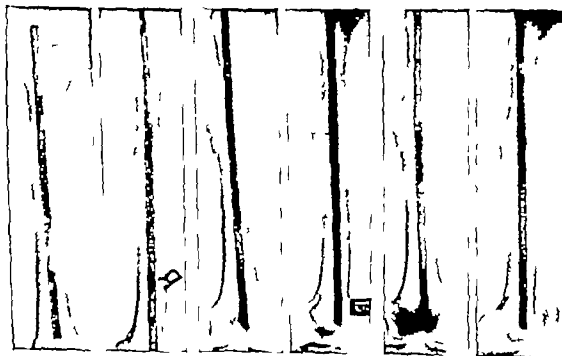


Fig. 717 Fig. 718
December 10 1943

Fig 719 Fig 720
February 16, 1944

Fig. 721 Fig 722
May 15 1944



Fig. 713 May 18 1943

Fig 714 October 29 1943

Fig. 713 Same case as Fig 705 Survey film to show angulation and shortening.

Fig 714 Same as Fig 713 5 months later Angulation corrected shortening now 7 cm., previously 8 cm.

Fig. 715 Same as Fig 714 after shortening of the right leg. Both thighs are now of equal length.

Fig 716. Same as Fig 715 after removal of both nails, 6 months after shortening of the right femur Bony union on both legs. On the right femur a varus angulation of 10° developed because the nail had been driven through the greater trochanter instead of medially from it and because the bone was severed 5 cm above the isthmus.

Figs. 717 718 Same as Fig 715 6 weeks after operation. Irritative periosteal appositions are seen on the lateral and posterior sides, due to play of the fragments since the bone was severed above the middle, where the medullary cavity of the proximal fragment is wider than the medullary nail.

Figs. 719 720 Same as Fig 715 15 weeks after operation. The osteotomy line is still visible marked irritative callus on the lateral and posterior aspects as in Figs. 390–407

Figs. 721 722. Same as Fig 715 after 6 months. Firm union with large callus. Varus of 10° recurvation of 4–5°

For the treatment of mal united femoral fractures the same *indications and contra indications* prevail as for old fractures of the femur (see pages 218 219) It must be added that even with a medullary nail the operation is difficult and in volves great responsibility it is not simple and easy as is frequently stated

The *case history* must be laid out in the same way as in old femoral fractures (see page 216)

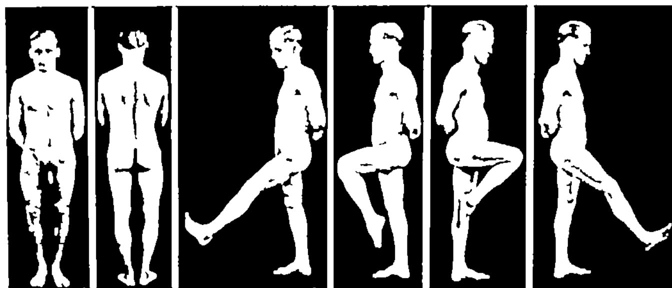


Fig. 729 Fig. 730 Fig. 731 Fig. 732 Fig. 733 Fig. 734

May 27 1944

Figs. 729–734 Same as Fig. 716, 12 months after the first and 7 months after the second operation. Both legs of equal length. On the right a varus of 10° Muscles are strong and all joints are actively free. Sustained walking without discomfort



Fig. 734 a and b

Fig. 734 a and b Since each leg is 8 cm. shorter than before the operations, the sciatic nerve is relatively too long The hip joints can therefore be hyperflexed.

Exposure of bone
Making of guide grooves
Osteotomy
Procedure upon encountering foci of infection,
Exposure of medullary canal
Removal of tourniquet
Hemostasis
Insertion of guide pins
Reduction of fragments
Checking of pulse
First X ray pictures
Driving the nail
Further X ray pictures
Supplementary wire suture
Insertion of drain

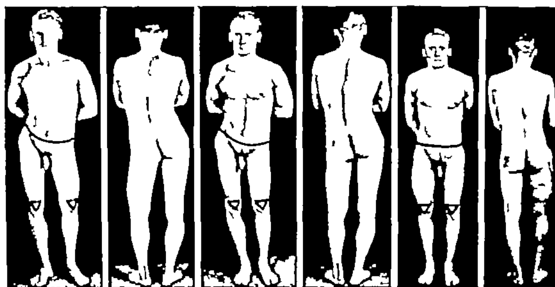


Fig. 723 Fig. 724 Fig. 725 Fig. 726 Fig. 727 Fig. 728
May 18, 1943 October 29 1943 November 11 1943

Figs. 723 724 Same case as Fig 713 before the first operation. Shortening 8 cm. varus 15° Obliquity of the pelvis and scoliosis of the spine.

Figs. 725 726. Same as Fig. 714 5 months after first operation Varus position corrected. Pelvic tilt and lateral curvature of the spine the same.

Figs. 727 728 Same as Fig 715 12 days after the second operation Both legs of equal length. Right thigh thickened because the muscles have not yet adjusted themselves to the shortening

Correction of shortening by continuous traction after osteotomy It is sometimes quite difficult to correct a shortening of more than 4 cm during the operation as great force is needed and much time consumed The tissues are being torn and thus the mobility is impaired Damage to nerve and blood vessels may result from the sudden stretching in the attempt to correct a marked shortening The prolonged duration of the operation may disturb the asepsis and lead to infection in the torn tissues. Therefore the shortening must be corrected before proceeding with the nailing With a tourniquet applied the bone is exposed through the lateral approach and severed as far as possible along the original fracture line with a chisel, Gigli saw or the circular saw A rubber drain is inserted, fascia and skin are sutured, and a pin or wire is inserted for weight traction as in the closed refracture of the callus If the original shortening was less than 4 cm. or if it was corrected by continuous traction and if the skin has healed with a healthy scar i e 2–4 weeks after osteotomy medullary nailing may then be performed

As described for the treatment of old fractures (see pages 219–223) the procedure entails the following

Determination of length and width of the medullary canal
Preparation of instruments and apparatus
Protection against heat loss
Availability of blood donor
Positioning,
Anesthesia,
Tourniquet,

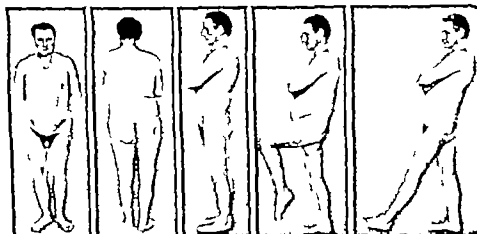


Fig. 739 September 17 1941 | Fig 740 November 26 1941 | Fig 741 Fig 742 February 22, 1943

Fig. 739 Same as Figs 737–738 4 months after bone grafting The greater part of the graft is absorbed. In spite of the Whitman cast a varus angulation of 20° recurred.

Fig 740 Same as Fig 739 2 months after closed nailing Beginning callus formation.

Figs. 741 742. Same as Fig 740, after 15 months. Fracture line still visible. Walks without discomfort.



Figs. 743–747
February 22, 1943

Figs. 743–747 Same as Figs 735–742 17 months after nailing. Muscles strong motion surprisingly good.

Open Medullary Nailing for Shortening of the Well Femur

If there is a marked shortening and circumstances do not permit a lengthening as in Figs 705 706 any angulation on the injured leg is corrected as described on

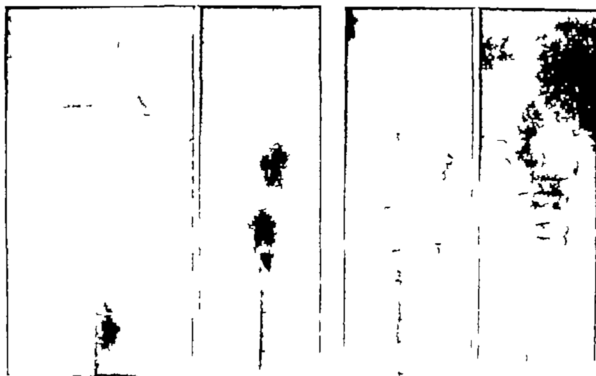


Fig. 735 Fig 736 Fig 737 Fig 738

May 16, 1941 May 23 1941

Figs. 735 736 A 16-months-old pseudarthrosis of the left femur with varus and antecurvation of 30° each, in a 35-year-old coachman weighing 95 Kg height 170 cm., who was run over by an automobile. Treated elsewhere with wire traction with 15–18 Kg. for 4 months, followed by hip spica for another 4 months.

Figs 737 738. Same as Figs 735 and 736. after transverse freshening of both fracture stumps and transplantation of an 11 cm. massive tibial graft, in excellent position A body hip spica from the toes to axilla with marked abduction was used for 3 months.

Closure of the wound
Post-operative positioning
Removal of drain
Exercises

In a fracture healed with angulation or rotation with negligible shortening, the degree of angulation is determined from cut-out transparent paper patterns of the bone made from tracings of the X ray pictures The pattern is then cut transversely but not completely towards the concave side at the level of the fracture and straightened out as in Figs II/2578 and 2581 Thus the size of the wedge which must be removed from the convex side by circular saw Gigli saw or chisel is determined

If the bone is cut transversely without removing a wedge callus formation will be delayed in the area of the isthmus and the medullary nail may break as in Figs 252–263 In fractures below the middle angulation may recur

In this operation the same circumstances that may lead to failure in old fractures (see page 223) must be observed.



Fig 750 Fig. 751 Fig 752 Fig 753

December 14 1942 May 22 1943

Figs. 750 751 Same as Figs. 748 and 749 after 7 weeks. Angulations and shortening almost corrected by wire traction. Medullary nailing.

Figs. 752, 753 Same as Figs. 748 and 749 after 7 months, and 5 months after medullary nailing. Bony union in good position.

drain, the periosteum fascia and the skin are closed Since the fracture is located within the isthmus of the medullary canal, no wire suture or additional external support is required (Fig 715) If however, the fragments still show rotatory play a wire suture must be used The leg is placed on a Braun frame The drain is removed after 24–36 hours. If the wound heals without disturbance the patient may get up after 2–3 weeks The operation is performed in the same manner as in old femoral fractures (see pages 219–223)

The most favorable situation prevails if the fractured leg shows only a shortening and no angulation or rotatory deformity Then this leg needs no attention, and a shortening of the well leg suffices K H Bauer described a case of this type Unfortunately they are rather rare

Open Medullary Nailing of Femoral Pseudarthroses

A pseudarthrosis of the femoral shaft constitutes such a serious disability that an orthopedic apparatus is needed for walking We therefore try to remedy this condition if the general condition of the patient and the local circumstances permit

Causes of pseudarthroses Formerly the main cause of pseudarthrosis was the extensive removal of bone splinters in compound fractures The French proceeded in particularly radical fashion during World War I The result was that in 37 736 gunshot fractures of the femur in the station hospitals 28 9 per cent (10 908) had to be amputated later for defect pseudarthrosis Such cases involving the femur are comparatively rare at present



Fig 748



Fig 749

October 22, 1942

Figs. 748, 749 A 3-months-old spiral fracture of the upper third of the right femur in a 22-year-old shoemaker from shell-fragment. Wound aseptic. After 3 days, wire transfixion hip spica. After 4 weeks, removal of the cast and passive exercises *elsewhere*. Varus 80° antecurvation 40°

pages 219–223 (Figs 707–710) After the patient has completely recovered from this operation the well femur is shortened to the length of the injured one Using a tourniquet the well femur is exposed above the middle and a guide groove of sufficient length is gouged into it to prevent a later rotation of the fragments. The bone is severed transversely with a Gigli saw between the proximal and middle third In Fig 715 the cut was made too high, therefore the medullary cavity of the upper fragment was somewhat wider than the nail thus permitting play and causing the formation of periosteal irritative callus (Figs 717–722) A piece of the required length is then cut off transversely from the distal fragment. Both saw-cuts are then located within the isthmus of the medullary canal. The guide pin is then inserted into the proximal fragment along the lateral wall of the medullary canal by so doing it emerges medial from the greater trochanter as in Fig 752 If it is brought out through the trochanter as in Figs 715 and 717 a varus angulation may develop subsequently as in Figs 719 and 721 Over the protruding guide pin a short nail is driven 1–2 cm into the greater trochanter The first guide wire is then removed from below and a new one is inserted through the medullary nail above until it emerges at the fracture The short nail which served merely as a temporary guide for the second pin is then removed This is followed by reduction of the fracture and X ray control. If the pictures show a satisfactory position of the fragments and proper location of the guide pin a medullary nail the length and thickness of which have previously been accurately determined is driven to the proximal saw-cut. The distal fragment is then placed over it and the nail completely driven in The guide groove in the bone prevents rotatory misalignment After the insertion of a



Fig 757 Fig 758 Fig 759 Fig 760

March 2, 1942 March 18, 1943

Figs 757 758. Same as Fig 756 after transverse freshening of both fragments 5 cm were removed from the distal fragment so that the fragments could be put in apposition without tension Medullary nailing. Drain.

Figs 759 760 Same as Figs 757 and 758. One year later and three months after extraction of the nail. Bony consolidation in good position. Knee 180–80° all other joints actively free Muscles strong

4 Shortening and angulation This must be corrected by continuous skeletal traction before nailing

5 Extensive ossifications in the medullary cavity

Marked impairment of the muscles and joints constitute no contra indication (Figs 771–783)

Correction of shortening and angulation Firm adhesions are loosened by manipulation over a wedge or by the Phelps-Gocht osteoclast (Figs 91 E I/108) If this does not cause a flare up of the infection in compound fractures such a flare up will probably not follow the nailing either Adequately heavy weight traction with pin or wires is then instituted In this way the shortening and the angulations can be corrected gently within a few days and during the operation the apposition of the fragments can be accomplished without force and damage to the tissues If the operation is performed while the shortening and angulation persist serious complications may arise In Figs 735–739 a varus angulation (Fig 739) recurred although an 11 cm well applied graft and a plaster cast from the axilla to the toes had been used therefore the graft became loose and was partly absorbed

In Fig 765 the strong pull of the adductors caused the nail to plow through the trochanter because it had been inserted too far laterally The forcible stretching of the muscles during the operation undoubtedly contributed to the flare up of the inflammation

In Figs 767–770 the medullary nail perforated the decalcified distal fragment



Fig. 754 Fig. 755 Fig. 756

January 16, 1941 February 6, 1942

Figs. 754, 755. Fracture of the right femur in a 32 year-old housewife who was run over by an automobile. Simultaneous crush injury of the left thigh necessitating immediate amputation. Treated *elsewhere* with 12 Kg. wire traction for 5 months, followed by hip spica for 4 months.

Fig. 756. Same as Fig. 754 after one year. Pseudarthrosis with varus of 65° and marked shortening due to lateral displacement and angulation.

Premature exercising does not usually lead to pseudarthrosis on the femur (Figs. 748, 749) in contrast to other bones.

The most common cause of pseudarthrosis in open and closed fractures nowadays is excessive skeletal pin or wire traction (Figs. 301–304). The amount of weight that may safely be used has been discussed on pages 103–106. Excessive traction was the cause of pseudarthrosis in Figs. 232–243, 735, 736, 754–756, 761–763, 767, 768 and 771, 772. Undoubtedly the time will come when the obstacles that now tend to prevent a proper organization of traumatic surgery will have been overcome (see pages II/1525–1530). Once we have independent departments for the teaching and practice of traumatic surgery, once femoral fractures do not come under the care of men lacking inborn aptitude, sufficient experience, or adequate equipment, then pseudarthrosis of this bone with its prolonged aftermath will be eradicated. In my experience this complication does not occur with equal frequency in all localities, but appears to be particularly abundant with certain individuals.

The contra indications against medullary nailing of pseudarthoses are the same as for old femoral fractures, viz.:

1. Impaired general condition.
2. Local inflammation on the bones. Sinuses must have been closed for a year. Under the protection of penicillin this period might possibly be reduced.
3. Pathologic conditions of the skin.



Fig 764
September 10 1942



Fig 765
October 17 1942



Fig 766
January 29, 1943

Fig 764 Same as Fig 761 after 11 months. 8 weeks after closure of the wounds medullary nailing was performed *elsewhere* without previous correction of the shortening The fragments were not sufficiently freshened the nail was inserted too far laterally

Fig. 765 Same as Fig 764 after 5 weeks. The nail plowed through the lateral wall of the greater trochanter Varus angulation recurred because the shortening was not corrected before the operation because the nail was driven to the lateral wall of the greater trochanter and because the operation was performed too soon i e 8 weeks after closure of the sinus, causing a flare-up of the inflammation.

Fig. 766. Same as Fig. 764 after removal of the nail and after insertion of a Steinmann pin into the greater trochanter by which the proximal fragment was pulled down. Varus angulation corrected. In this position a body-hip spica was applied. 6 months later the fracture was firm and in good position. All joints are stiff If this gunshot fracture had not been distracted it would probably have healed in good position in 8–10 weeks firmly enough for weight-bearing and the motion of the joints would not have been impaired.

In cases with shortening or defect pseudarthrosis a massive graft of proper length must be transplanted It must overlap both fragments at least 5 cm If medullary nailing is used in addition the immobilization is so much the better

The advantages of technically correct medullary nailing and the complications arising from improper indication and defective technique are best illustrated by Figs 735–783 and their case histories

Case 1 Excessive wire traction elsewhere caused delayed callus formation in a 35-year-old man. Immobilization in plaster for 4 months did not halt the development of pseudarthrosis (Figs. 735 736) The exposure of the fist-sized pseudarthrosis was quite difficult Both fragments were cut transversely A piece 5 cm long was cut out along the outer side of the proximal fragment and a 6 cm -piece from the distal fragment thus exposing the medullary cavity for a distance of 11 cm. Each fragment was drilled transversely in 3 places The fragments were apposed by a longitudinal wire suture Wires were put through the remaining four drill holes A graft with periosteum 11 cm long was removed from the tibia, consisting of half the thickness of this bone It was fastened to the prepared femoral bed by encircling it one and a half times with the 4 wires. The union was so firm that the leg could be lifted and moved in all directions without noticeable play at the juncture. A large drain was inserted The periosteum fascia and skin were sutured



Fig 761
October 4 1941



Fig. 762
October 19 1941



Fig. 763
March 10 1942

Fig. 761 Gunshot fracture of the right femur upper third with large soft tissue injury and extensive damage to the muscles, 5 days after injury in wire traction. A 27 year-old man 165 cm. in height, weight 54 Kg., wounded by bomb fragment. Wound infected. Wire traction with 7 Kg. Fragments distracted.

Fig 762. Same as Fig. 761 after 15 days. Angulation eliminated. More separation of the fragment.

Fig. 763 Same as Fig 761 after 5 months. Wire traction was removed after 11 weeks, then merely placed on Braun splint. Varus of 60° The fracture surface of the proximal fragment is ground smooth no callus formation.

because axial alignment without a preliminary correction of the shortening and angulation was too difficult

In Fig 756 the shortening was not corrected by continuous traction. Since the other leg had been amputated the remaining one was shortened by 5 cm , in this way it was possible to approximate the fragments without difficulty

Medullary nailing of pseudarthrosis After correction of the shortening by continuous traction (see page 235) the operation is performed in the same way as in old fractures of the femur (see pages 219–223) The exposure of the fragments is frequently difficult because of extensive scarring As soon as the fragments are freshened the nail may be driven in over the guide pin The operation lasts only a short time and the fragments are firmly united if the technique has been correct It must be emphasized that the fragments must be freshened and coapted thoroughly Many failures are due to the neglect of this in the belief that the medullary nail stimulates callus formation (see pages 90–136 and 139–141)

Before the medullary nail came into use bone grafts had to be used frequently The fragments had to be cut out lengthwise and drilled A large graft from the tibia was fitted into the femur and fastened with wire (Figs 737 738) This operation took much more time Furthermore a large plaster cast had to be applied. In contrast to this, medullary nailing does not as a rule require supplementary external support in fractures above the middle In oblique fractures a circular wire suture is applied.

although union was not yet firm He was able to work in spite of a persistent pseudarthrosis similar to the man of Figs 618-638 With any other method, this would have been unthinkable

Case 2 In a 28-year-old man the cast was removed elsewhere after 4 weeks to apply massage and passive motion Marked angulation and shortening (Figs 748 749) ensued These deformities were corrected by wire traction (Figs 750 751) Three weeks after open medullary nailing he was able to get about without supplementary plaster cast because the fracture was located within the narrowest area of the medullary canal Five months later the fragments had united by bone (Figs 752 753)

In this case the operation was comparatively simple because the angulations and the shortening had been eliminated before the nailing, and the result was perfect

Case 3 In a 32 year-old woman excessive traction caused separation of the fragments and a pseudarthrosis developed although a hip spica had later been applied for four months (Fig 756) After medullary nailing bony union in good position was obtained (Figs 759 760)

In this case the shortening of the muscles was not corrected by continuous traction but by shortening of the bone, which was the simplest and most effective procedure in view of the loss of the other leg

Case 4 In a 27 year-old man with a subtrochanteric gunshot fracture the fragments separated although only 7 Kg had been used for wire traction (Figs. 761 762) When traction was removed after 11 weeks, marked angulation and shortening (Fig 763) developed because callus had formed since the fragments were gaping. Without preliminary correction of the deformities the fracture was nailed 8 weeks after closure of the sinuses (Fig 764) After 5 weeks the nail plowed through (Fig. 765)

Since this patient weighed only 54 Kg, traction with 7 Kg was too much Since it was an infected gunshot fracture, no more than 5 Kg should have been used (see page 104) Since the traction was removed in spite of lack of callus and no cast was applied marked angulation and pseudarthrosis followed (Fig 763) The nailing was performed without preliminary correction of the deformities, therefore it was very difficult. Since the sinus had been closed only 8 weeks instead of one year the forcible maneuvers caused a flare up of the inflammation and additional decalcification. The nail which had been inserted slightly lateral from the tip of the greater torchanter, was therefore able to plow through the lateral wall of the bone, thus losing its hold The nail was then removed

In this case the operation should have been delayed for 10 more months Preceding it the proximal fragment should have been pulled down by an obliquely inserted Steinmann nail (Fig 766) In such old fractures, it is not sufficient to exert merely longitudinal traction at the lower end of the femur

Case 5 In a 33-year-old man pseudarthrosis shortening and angulation (Figs. 767 768) developed because of excessive traction Ten weeks after closure of the sinuses medullary nailing was performed without previous correction of the deformities the result was poor

In this case heavy weights of 12–14 Kg had been used for a long period in spite of infection Despite prolonged immobilization in a plaster cast, a pseudarthrosis



Fig 767 Fig 768 Fig 769 Fig 770

February 4 1943 February 15 1943

Figs. 767 768 A 22 months-old pseudarthrosis of the right femur in a 33-year-old cabinetmaker from gunshot. Wound infected Wire traction of 12 Kg for 6 weeks, then hip spica for 10 weeks, then again wire traction with 14 Kg for 4 months and again hip spica for 5 months. Varus 50° antecurvation 40° Shortening 10 cm.

Figs. 769 770 Same as Figs. 767 and 768 after medullary nailing performed elsewhere. Since the shortening was not corrected pre-operatively it was not possible to correct the varus angulation completely The nail therefore penetrated through the decalcified distal fragment.

X-ray pictures (Figs 737 738) show ideal position of the fragments and of the graft. As an added safeguard a large plaster cast from the axillae to the toes was applied with considerable abduction. After 6 weeks X ray pictures through the cast show recurrence of a slight varus angulation. After removal of the cast 4 months later the X ray pictures show a partial absorption of the graft and a bowing (Fig 739) Clinically slight motion was present at the fracture site For this reason a medullary nail was driven in with great difficulty without exposing the fracture (Fig. 740) It was not possible to drive it through the greater trochanter because of the angulation, therefore it had to be driven in through the lateral aspect of the trochanter With this the patient was able to walk after 3 weeks without supplementary support. After 17 months the fracture line was still visible. When the nail was then removed, the fracture was still loose and further bowing occurred Therefore another medullary nail was inserted

The failure of this grafting operation was due to the fact that the angulation and the contracture of the adductors were not corrected before the operation Neither the long strong graft with 4 wire sutures nor the large plaster cast could prevent angulation The great advantage of the medullary nail in this patient was the fact that he was able to get about without a plaster cast without being exposed to the danger of further bowing permitting his joints and muscles which had become stiff and weak during the long immobilization in the plaster cast to recover (Figs 743–747),





Fig. 775 Fig. 776
February 8 1943

Figs. 777–779 November 25 1941
Figs 780–783 February 17 1943

Figs. 775 776. Same as Figs. 771 and 772, after 14 months 8 days after removal of the nail. Fracture united with 10° varus angulation Bony consolidation

Figs. 777–779 Same as Figs. 771 and 772. The thigh can be bent in all directions at the fracture site

Figs. 780–783 Same as Figs. 775 and 776. Fracture firm and able to bear weight Shortening 2.5 cm. Knee stiff as before the operation the other joints actively free

By thorough excision primary healing of the wound was obtained Because the traction was too strong however callus formation was delayed When deformity developed in a plaster cast traction was again applied with too much weight This caused a wound infection It took a year and a half for the sinuses to close When we saw her soon thereafter we told her to return in a year The shortening and angulation were then corrected in the course of 6 days by continuous pin traction with 10–14 kg The fragments were then freshened and nailed Since the fragments were decalcified and showed angulatory and rotatory play after nailing a supplementary hip spica was applied After 7 months the fracture showed bony consolidation (Figs 775 776) and the leg was fit to bear weight (Figs 780–783)

Case 7 is discussed in the legends of Figs. 232–243 and *Case 8* in the legends of Figs. 344–351

Summary These 8 case histories prove the following

1 In infected fractures operation without penicillin must not be performed sooner than one year after closure of the sinuses otherwise a flare up of the infection



Fig. 771 Fig. 772 Fig. 773 Fig. 774

November 26 1941 June 29 1942

Figs. 771 772. A 2½ year-old pseudarthrosis of the left femur following *compound* fracture in a 34-year-old working-woman height 158 cm weight 70 Kg., who was caught by a street car while riding in the sidecar of a motorcycle. *Elsewhere* wound excision and continuous traction with 10 Kg. for 5 weeks. Wound healed without inflammation Then plaster cast for 12 weeks. Since the fracture had not united, again continuous traction with 10 Kg for 16 weeks, gradually reduced to 2 Kg The wound became inflamed during this traction Then again, hip spica. Treated later by a lay practitioner with a tree-bark dressing on the femur Suppuration for 1½ years. After 2½ years no trace of callus formation. Fragments markedly angulated, overlapping 5 cm. Marked decalcification. Tibial pin traction with 10–14 Kg for 6 days until the shortening was corrected. Then medullary nailing and hip spica for 6 months.

Figs. 773 774 Same as Figs. 771 and 772, 7 months after nailing Good position and good callus formation.

developed (Figs 767 768) The operation should have been delayed for one year after closure of the sinuses rather than performed after only 10 weeks The operation was difficult because the shortening had not been corrected previously Since the guide pin had not been introduced into the distal fragment and since no X ray pictures were taken before the driving of the nail to check the position of the fragments the nail perforated the lateral wall of the decalcified distal fragment. Therefore immobilization was decidedly poor A violent infection of the fracture followed leading to metastatic lung abscesses and pleural empyema of which the man died.

Case 6 In a 34-year-old woman with a compound femoral fracture, a pseudarthrosis (Figs 771 772) developed from excessive wire traction One year after closure of the sinuses freshening of the fragments and nailing was followed by bony union (Figs. 775 776)

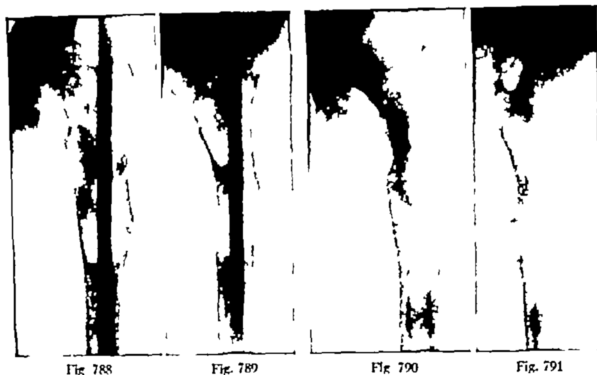


Fig 788 Fig. 789 Fig. 790 Fig. 791

August 19 1942 February 18 1943

Figs. 788, 789 Same as Figs. 784–787 after 2 months. The fracture shows bony union Cyst has become calcified. No pain Able to walk all day long without discomfort.

Figs. 790 791 Same as Figs. 784–787 immediately after removal of the nail and 8 months after nailing. The region of the cyst shows good calcium content. No discomfort All joints actively free

Closed Medullary Nailing in Localized Osteopathia Fibrosa Cystica

Localized ostitis fibrosa cystica (brown tumor) is most frequently located in the proximal third of the femur and the humerus and develops comparatively rarely in other bones. It is a typical pressure disease The pressure of the fluid inside the bone causes an absorption of cortex until this is eventually reduced to paper thinness (Figs 784 785) because no periosteal apposition takes place concurrently with the absorption from inside A slight injury, such as slipping or twisting may cause a fracture of the pathologically affected bone This opens the wall of the cavity and the pressure is released Bone production begins and the fragments usually unite Sometimes the cyst heals Usually, however a new cyst develops because the wall of the cavity closes again and its pathologic contents are thus once more put under pressure

The disease can be cured by a wide exposure and thorough curetting of the cavity and preferably the insertion of a massive bone graft after removal of the diseased tissue

In one such case Eigenthaler inserted a medullary nail This procedure alone, without curetting or a graft led to a cure

Case history A 32 year-old woman who had complained of pain in the left knee for 4 months had been treated elsewhere with injections for rheumatism and with baking When she came to us the X ray pictures showed a cyst, 7 cm long with a paper thin wall (Figs 784 785) in the upper third of the left femur In lateral recumbency with the hip flexed at a right angle a 2 cm. incision



Fig. 784 Fig. 785 Fig. 786 Fig. 787

June 17 1942 June 17 1942

Figs. 784, 785 Ostitis fibrosa cystica in a 32 year-old housewife who had pain in the left knee joint for 4 months and was treated with injections and baking The cortex has almost completely disappeared, is paper thin

Figs. 786, 787 Same as Figs. 784 and 785 after insertion of the medullary nail. In piercing the bone with a guide pin the leg was twisted slightly and broke obliquely through the cyst. Was able to get up after 5 weeks and left the hospital after 6 weeks.

is the rule This may lead to plowing of the nail (Case 4 and Fig 765) or to death (Case 5 and Figs 767–770)

2 Angulation and shortening must be completely corrected before operation, either with the Phelps-Gocht osteoclast or by continuous traction because their correction during the operation is very difficult The latter prolongs the procedure and damages the tissues so that infection may follow The pull of shortened muscles may cause re-angulation (Figs 739 765)

3 The nail must not be driven in until after the guide pin has been introduced into the distal fragment and its position checked by X ray pictures in 2 planes (Figs 707 708) Otherwise it may perforate the decalcified bone as in Figs 769, 770

4 Pseudarthroses of the femur will unite if they are exposed and freshened (Figs 752 753 759 760 775 776) If they are not freshened they will persist as a rule (Figs 741 742) but occasionally they may unite Even with persisting pseudarthrosis the patient of Figs 743–747 is able to work as is true of the case of Figs 618–638

5 In a pseudarthrosis above the middle no supplementary immobilization with a plaster cast is needed (Figs 740–742 752 753 758) In nailed pseudarthroses below the middle a wire suture is required similar to Figs 709 710, which obviates the necessity of a cast.

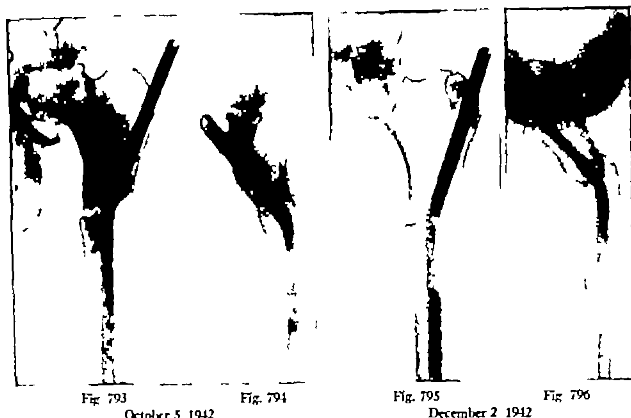


Fig 793 Fig. 794 Fig. 795 Fig 796
October 5 1942 December 2 1942

Figs. 793 794 Same as Fig. 792 after insertion of the nail, severing of the bone with a Gigli saw and removal of a wedge on the outer side. The distal fragment was then bent outward and forward until both legs were of the same length.

Figs. 795 796. Same, after 2 months. Good callus formed.

The curetting of a cyst and the implantation of a graft constitute a comparatively major procedure whereas closed nailing is technically simple and not dangerous The after treatment consists merely in placing the leg on a Braun frame A large cast is unnecessary because the nail provides sufficient stability Attempts have been made to treat this disease with roentgen irradiation I have never seen success from it Recently a case came to my attention with marked skin changes from irradiation while the tumor itself showed sarcomatous degeneration 6 years after the X ray treatments

Küntscher recommended medullary nailing for metastases of malignant tumors which are also frequently located in the upper third of the femur Such patients with spontaneous fractures can be made to walk again because the nail can carry the weight although the bone does not unite That patients with femoral pseudarthrosis are fully able to work with a medullary nail although the fracture is not firm is shown in Figs 626–638 and 741–747

Closed Medullary Nailing in the Treatment of Contractures of the Hip

In a contracture of the hip with flexion adduction and internal rotation following fracture dislocation (Fig 792) Güttner proceeded in the following manner He inserted a guide pin into the femur in the usual way and drove a thin medullary nail



Fig. 792
October 4 1942

Fig. 792 A 9-months-old fracture dislocation of the left hip with marginal fracture of the roof of the posterior part of the acetabulum with adduction, inward rotation and flexion of the thigh, in a 42 year-old forester who was struck by a tree trunk Treated *elsewhere* with wire traction with 7 Kg for 6 weeks. For this type of fracture dislocations 10–12 Kg traction is needed for 12 weeks (see vol. II page 801)

was made 5 cm. above the tip of the greater trochanter and a guide pin was inserted. During a slight *twist of the leg the bone broke obliquely from medial above to downward laterally* The nail was then driven in over the guide pin and the wound closed with 2 sutures (Figs 786 787) The fracture led to a longitudinal displacement and the bone became 6 mm. shorter The leg was placed on a Braun frame The pressure pains disappeared after nailing After 8 days local tenderness had disappeared After 14 days, she was able to raise the leg actively from the bed which she had been unable to do before the operation After 3 weeks, she started exercises on the knee-exerciser (Figs II/1574 1575) Five weeks later she got up and in the sixth post-operative week she left the hospital without discomfort. X ray pictures taken after 2 months showed good callus formation at the fracture site and a thickening *of the cyst wall* (Figs. 788 789) She was able to follow her usual work unhampered When the X ray pictures 8 months later showed normal bone density in the region of the cyst the nail was removed under local anesthesia (Figs 790 791) Re-examination 2½ years later showed no recurrence.

This case offers conclusive evidence that localized ostitis fibrosa cystica is a disease produced by pressure within the bone By the insertion of the nail the cyst was opened and its contents could empty continuously In contrast to a spontaneous fracture *the wall of the cavity could not close and thereby renewed accumulation* of pressure was prevented. Since pressure from within was eliminated bone formation was undisturbed The fracture that occurred during the insertion of the guide pin produced a wide opening of the cyst and the slight shortening merely enhanced the healing process.

For such cases I would recommend exposure of the humerus with careful preservation of the radial nerve then severing the bone transversely and overlapping it until the nerve stumps can be pulled up far enough for approximation without tension The bone is then shortened by / shaping the ends and uniting them with a medullary nail and a wire suture The nerve stumps can then be sutured

In sciatic paralysis defects of the sciatic nerve up to 7 cm can be sutured without tension by flexing the knee For larger defects this is not sufficient I would then recommend a shortening of the femur by 5 or 6 cm since this is the lesser evil as compared with a sciatic paralysis with trophic ulcers on the heel and on the toes In exceptional cases the other femur could be shortened for equalization This recommendation can be justified only because, with a medullary nail we are able to restore the original stability of the bone without additional splinting immediately after the operation. By shortening the femur by 5 cm and flexing the knee nerve defects up to 12 cm can be bridged without tension

"For nerve defects on the lower leg bone shortening can hardly come into consideration "

According to my experiences to date, nailing comes into consideration for bone shortening only on the femur On the humerus and forearm it offers no advantage over step-freshening yet entails great dangers

Time of operation If electric examination reveals complete interruption of nerve conduction, one should proceed with operation as soon as possible to prevent degenerative changes from progressing further In infected cases one must delay the operation 4–12 months after the closure of all sinuses The time depends upon the severity of the original infection If, for instance, in a gunshot fracture of the humerus, a sinus drains for 9 months without ever causing fever or signs of inflammation, and if the sinus closes a few days after removal of a sequestrum or of a metal splinter which had maintained the suppuration, one may proceed with nerve suture as early as 4 months after closure of the sinus If, however, a putrid infection with high temperatures had been present, and even if the wounds closed within 3 or 4 months, one must wait at least 1 to 2 years before undertaking nerve suture, otherwise, a flare up of the infection and a separation of the sutured nerves will follow Under the protection of *penicillin*, nerve suture may possibly be carried out sooner

Many recommend the sheathing of the nerve with beef artery, pieces of the saphenous vein or with a hernial sac. In my opinion the best procedure is to place the nerve in a surrounding muscle from which the scars have been removed as thoroughly as possible. Any sheathing of the sutured nerve leads to scar formation and sometimes to stricture, as I have observed If in these cases a stricture caused by the sheathing material is released, nerve conductivity may return within a short time I therefore do not recommend any kind of sheathing

Tendon transplantations should be considered only if nerve suture has proven unsuccessful after one year or if it was impossible to carry out

Open Medullary Nailing after Bone Shortening for Vascular Defects from Gunshot Injuries

If a vascular defect results from an operation for aneurysm, suture of the blood vessels is sometimes possible by flexing the joints Otherwise ligation or transplantation of a piece of vein from the saphenous or femoral vein is the only alternative

over it The femur was then exposed laterally and severed in the upper third with a Gigli saw Postero-laterally a wedge with 1 cm base was sawed off The leg was then bent outward and backward until both malleoli touched and until the lordosis of the spine was reduced to one half X ray pictures then showed 20° valgus angulation and 30° antecurvation between the fragments (Figs 793, 794) A drain was inserted, the wound closed in layers, and the leg placed on a Braun frame After 4 weeks the man was able to get up without a cast. Good callus formation (Figs. 795, 796) could be seen 8 weeks later After 5 months the nail was extracted. This method has the advantage that no plaster cast is needed after the operation and that the fragments cannot be displaced However, all advantages of the closed medullary nailing are nullified by subsequent open osteotomy Therefore, we will not use this method again, but perform the usual closed osteotomy between the greater and minor trochanters through a 2–3 cm incision as the simpler and less dangerous procedure, in preference to the nailing

Open Medullary Nailing after Bone Shortening for Nerve Defects from Gunshot Injuries

In nerve sutures a good result may be expected only if the nerve stumps can be united without tension after thorough removal of the scar tissue This is sometimes rather difficult to accomplish when extensive scarring or a defect from gunshot injury must be dealt with, even if acute flexion of the joints is used to shorten the course of the nerve I have not seen much success from neuroplasties and nerve grafts.

As early as 1906, Perthes recommended a shortening of the humerus if it was not possible to unite nerve stumps without tension after freshening This method was not used frequently because osteosynthesis with wires or Lane plates and screws was rather circumstantial and did not provide sufficient stability to obviate additional fixation by plaster or splints.

In the 1st to 8th editions I made the following statements

"Since Küntscher's medullary nailing provides an ideal method for a firm osteosynthesis without additional external support, for cases requiring nerve sutures I recommend bone shortening not only in injuries of the upper arm but also those of the forearm the cervical plexus, the femur and the lower leg

"Forearm gunshot injuries with nerve defects are usually accompanied by muscle defects and shortening of tendons with marked limitation of finger motions If the nerve ends cannot be approximated without tension, both forearm bones may be shortened and provided with a medullary nail. This also creates more favorable conditions for the shortened muscles. The bones must be freshened obliquely or Z-shaped because transverse freshening frequently leads to pseudarthrosis (Figs 1166–1171, 1210–1219)

"Subcutaneous injuries to the cervical plexus are usually caused by sudden depression of the shoulder girdle, as most frequently occurs in motorcycle accidents when the shoulder strikes against a tree or a telegraph pole with full force. The nerve roots are thereby torn out from the spinal cord Suture is not possible. Nerve grafting has been tried Whether recovery should be credited to such measures is difficult to decide, because I have seen complete recovery from paralysis in conservatively treated cases after as much as one year In gunshot injuries of the cervical plexus, approximation of the stumps and suture can easily be carried out, provided no infection has set in. However if extensive laceration or suppuration has caused defects in the nerves, it is sometimes impossible to approximate the stumps without tension even by elevation of the arm.

For such cases I would recommend exposure of the humerus with careful preservation of the radial nerve then severing the bone transversely and overlapping it until the nerve stumps can be pulled up far enough for approximation without tension The bone is then shortened by Z shaping the ends and uniting them with a medullary nail and a wire suture The nerve stumps can then be sutured

"In sciatic paralysis defects of the sciatic nerve up to 4 cm can be sutured without tension by flexing the knee For larger defects this is not sufficient I would then recommend a shortening of the femur by 5 or 6 cm since this is the lesser evil as compared with a sciatic paralysis with trophic ulcers on the heel and on the toes In exceptional cases the other femur could be shortened for equalization This recommendation can be justified only because with a medullary nail we are able to restore the original stability of the bone without additional splinting immediately after the operation By shortening the femur by 5 cm and flexing the knee nerve defects up to 12 cm can be bridged without tension.

"For nerve defects on the lower leg, bone shortening can hardly come into consideration"

According to my experiences to date, nailing comes into consideration for bone shortening only on the femur On the humerus and forearm it offers no advantage over step-freshening, yet entails great dangers.

Time of operation If electric examination reveals complete interruption of nerve conduction, one should proceed with operation as soon as possible to prevent de generative changes from progressing further In infected cases one must delay the operation 4–12 months after the closure of all sinuses The time depends upon the severity of the original infection. If, for instance, in a gunshot fracture of the humerus a sinus drains for 9 months without ever causing fever or signs of in flammation, and if the sinus closes a few days after removal of a sequestrum or of a metal splinter which had maintained the suppuration, one may proceed with nerve suture as early as 4 months after closure of the sinus If, however, a putrid infection with high temperatures had been present, and even if the wounds closed within 3 or 4 months, one must wait at least 1 to 2 years before undertaking nerve suture, otherwise, a flare up of the infection and a separation of the sutured nerves will follow Under the protection of *penicillin*, nerve suture may possibly be carried out sooner

Many recommend the sheathing of the nerve with beef artery, pieces of the saphenous vein or with a hernial sac. In my opinion the best procedure is to place the nerve in a surrounding muscle from which the scars have been removed as thoroughly as possible Any sheathing of the sutured nerve leads to scar formation and sometimes to stricture, as I have observed If in these cases a stricture caused by the sheathing material is released, nerve conductivity may return within a short time. I therefore do not recommend any kind of sheathing

Tendon transplantations should be considered only if nerve suture has proven unsuccessful after one year or if it was impossible to carry out.

Open Medullary Nailing after Bone Shortening for Vascular Defects from Gunshot Injuries

If a vascular defect results from an operation for aneurysm, suture of the blood vessels is sometimes possible by flexing the joints. Otherwise ligation or transplan tation of a piece of vein from the saphenous or femoral vein is the only alternative

Instead of this, one may shorten the bone and provide it with a medullary nail which is simpler and less dangerous than vein transplantation

FRACTURES OF THE LOWER LEG

Closed Medullary Nailing of Lower Leg Fractures

General requirements with regard to the patient Closed medullary nailing of the lower leg requires that the patient be in a good general condition Heart lungs

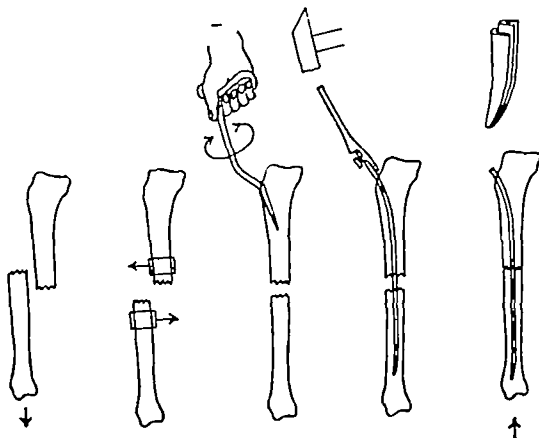


Fig 796, a–e

Fig. 796, a. Transverse fracture of the tibia with marked shortening and lateral displacement.

Fig. 796 b. The shortening is corrected by longitudinal traction. Lateral traction straps are applied for correction of the lateral displacement, as in Fig 804

Fig. 796 c. With a curved-handled awl (Fig 72) the cortex is pierced obliquely on the medial side of the tibial tuberosity as in Figs. 797–800

Fig. 796 d. The nail, held in Kuntscher s handle (Fig 77) is driven in.

Fig 796, e. After the nail is in the right position the fragments are impacted.

kidneys reflexes joint motion and sensation must be carefully checked The skin must be normal and show no injury or inflammation even outside the fracture area. Also, infections in other parts of the body (e g tonsillitis etc) must not be present.

Local requirements with regard to the patient Closed transverse fractures in the middle third are best suited to medullary nailing (Figs 816–823) They should be no more than 10 cm removed from the proximal or distal end of the tibia

Closed oblique and spiral fractures in the middle third are equally suited In the lower third nailing should be done only if the fragments are displaced by the full thickness of the shaft and can be aligned only with difficulty by continuous traction With the split nail of Maatz it might be possible to nail fractures less than 10 cm from the distal end of the tibia

Old transverse fractures in the middle third slightly lower than in Figs 244–251, are sometimes suitable for nailing Osteotomy of the fibula is however, as a rule preferable

Contra indications with regard to the patient If the general condition is poor (weak rapid pulse, pale appearance, cold sweat), nailing must not be done under any circumstances because it is no emergency procedure **If the patient is in**

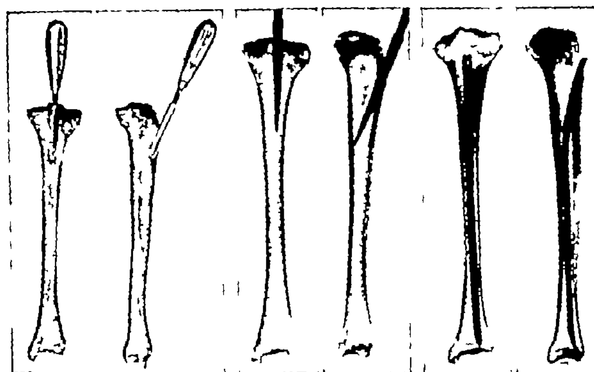


Fig. 797 Fig. 798 Fig. 799 Fig. 800 Fig. 801 Fig. 802

Figs. 797 798 Making a hole with the awl near the tibial tuberosity

Figs. 799 800 X ray pictures of Figs. 797 and 798. The awl penetrates obliquely through the bone towards the posterior wall. Pictures made by Güttner

Figs. 801 802. The medullary nail strikes the posterior wall between the middle and upper third and is then deflected against the anterior wall which it reaches at the junction between the middle and lower third It then slides along the anterior wall to the lower end of the tibia.

profound shock as is frequently the case with multiple injuries, medullary nailing must definitely be omitted because the outcome may be fatal (see page 8) With poor general condition only a wire or pin traction or a cast may be used

Contra indications with regard to the soft tissues In the presence of *inflammatory conditions of the respiratory organs the digestive or genito-urinary tract,* closed medullary nailing must not be done because the infection might spread into the medullary cavity Tonsillitis is particularly dangerous.

If *inflammatory skin conditions* especially furunculosis, are present, nailing must be avoided because of the danger of metastatic infection

If *burns* are present especially on the injured limb nailing should not be done (Figs 169–178)

In the presence of *wounds in other parts of the body*, nailing must be delayed until they are entirely healed, i e , about 14 days after the injury, otherwise, late inflammation and metastatic infection may occur (see pages 9 and 151)

In the presence of *deep abrasions* over the fracture, one must not nail because necrosis of the contused skin may lead to exposure and infection of the immediately underlying fracture, especially on the lower leg and on the forearm (see page 151)

In the presence of *marked swelling* nailing must be deferred until the swelling has subsided.

If *tension blebs* indicate a marked interference with the circulation, nailing must be omitted

Skin changes due to *varicosities* constitute a contra indication against nailing Stotz reports a case of death in such an instance (see page 152)

Contra indications with regard to the bone Comminuted fractures, spiral frac tures with a long butterfly fragment and fractures in bone diseases in which the medullary cavity is blocked as in certain forms of Paget's disease, are not suitable for nailing

The fractures must be at least 10 cm removed from the proximal or distal end.

Tabes is no contra indication

Requirements from the surgeon He must be experienced in bone surgery and must have at his disposal the instruments and apparatus listed on pages 22–26

Local anesthesia and X-ray pictures Absolute prerequisites for medullary nailing are good X ray pictures of sufficient size from both sides. To avoid pain while taking the lateral views, local anesthesia of the fracture site (see page I/99) is indicated The pictures must be at least 40 cm long (Figs 807–823) to obtain a good overall view to avoid overlooking other injuries (Figs. 816–823) and for ac curate measuring of the width of the medullary canal. One of the two joints must be in view

Time of operation If the patient is in good general condition the operation may be performed within the first few hours. The fragments can best be reduced on the first day, *before the hematoma and the swelling increase* *If it was impossible for* some reason to perform the operation within the first few hours, it may be per formed within the next few days provided the swelling is slight. If it is marked and causes the skin to have a shiny appearance one must not operate until the swell ing has subsided If deep abrasions are present on the broken leg especially over the tibial crest, medullary nailing must not be carried out even later With wounds on the broken leg outside the fracture or on other parts of the body nailing must be delayed for at least 2–3 weeks until they are entirely healed unless it can be done immediately following debridement otherwise the wounds may break open become inflamed and cause a metastatic infection of the fracture (see pages 9 and 151)

Determination of length width and curve of the medullary canal As soon as the X ray pictures are finished and the time for the operation has been set the length of the well tibia is measured This is done with the knee at a right angle because this permits more reliable palpation of the tibia at its upper border The measurement is taken to the tip of the internal malleolus This malleolus is usually 12–20 mm high (average, 16 mm) Since the nail should reach to within 1–2 cm from the joint 3 cm are next subtracted from the measurement of the entire bone

Later when the leg is in the reduction apparatus and the fracture has been reduced, the nailing site on the medial side of the tibial tuberosity is marked and its distance from the upper border of the tibia is measured this, too, is then subtracted from the measurement of the entire bone, and thus the length of the nail to be selected is attained Up to the present, the majority of disturbances have arisen from the selection of too short or too thin a nail (Figs 202–212, 224, 225, 442–459) Disturbances arising from nails which are too long are rare but serious, because if infection should supervene it might involve the talocrural joint (Figs 213–221, 894–901) Disturbances due to the use of too thick a nail were observed only once in our experience (Figs 153–160)

The width of the medullary canal is then measured from the X ray pictures The narrowest region varies in adults between 7–12 mm It is located at the junction between the middle and the lower third The entire middle third is comparatively narrow (Figs 12–20) If the X ray pictures were taken at a focal film distance of 80 cm , then 1–2 cm must be deducted from the measurements If too thick a nail is chosen difficulties will be encountered early in the operation (Figs 153–160), because it cannot be driven in far enough If it is too thin and too short, angulations (Figs 202–212) or rotatory displacement will occur later (Figs. 224–231) Stotz reports severe infection in two cases in which a nail which was too thick could neither be driven in nor retracted, in one of these cases he sawed the nail off, in the other he chiseled it out of the bone

If the length and thickness of the nail have been accurately determined beforehand it will not be necessary to have a whole set sterilized only to discover during the operation that no suitable nail has been included Case histories show that this was the simple reason why a nail which was either too long or too thick or too thin had to be used I must re-emphasize the fact that medullary nailing is not an emergency procedure and therefore not a measure that *must* be carried out under all circumstances but one which is *permissible only* if the right nail is on hand.

Personnel An anesthetist who also supervises the general condition of the patient (pulse, appearance) a fluoroscopist, an instrument nurse and an X ray technician are needed for help

Anesthesia On the first day, the local anesthesia used for the X ray pictures is sufficient for the reduction For the small transverse incision and for the driving of the nail, local infiltration medial from the tibial tuberosity is sometimes adequate If the driving of the nail causes pain in spite of this, the analgesic stage of a general anesthetic is used. For patients in good general condition spinal anesthesia is

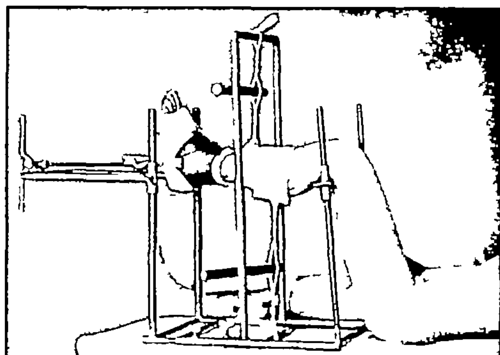


Fig. 803

Fig 803 The lower leg is fastened in the screw traction apparatus ready for nailing. The patient lies on his back. The hip and knee are bent to a right angle. Longitudinal traction is exerted by the leather foot hitch, which corresponds to the upper part of a shoe. Straps to the crossbars secure the leg in the antero-posterior plane. If necessary additional straps can be applied in the frontal plane. With the windlass strong easily regulated lateral traction can be exerted.

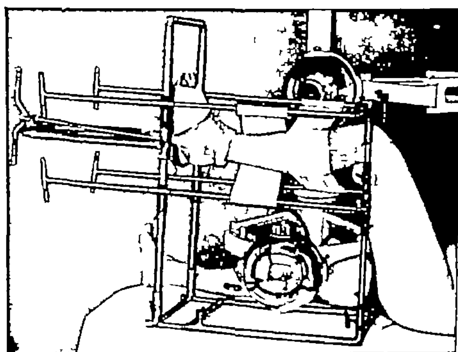


Fig. 804

Fig. 804 The lower leg is firmly secured for medullary nailing by traction on the foot-hitch and by lateral straps which are tightened by the rotating double bars. The X-ray tubes are in position for fluoroscopy and roentgenography For better illustration the lateral X-ray tube has been placed too high. (For description of this apparatus, see pages 29–31

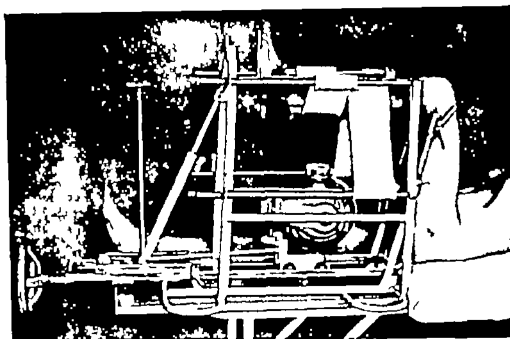


Fig. 805

Fig 805 Lower leg fracture secured in Linsmayer's apparatus. The lateral X ray tube has not yet been put in place. The posterior tube moves on a little carriage with ball bearing wheels. For description of this apparatus, see pages 27–29

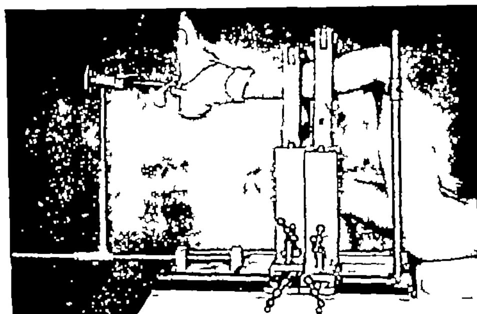


Fig 806

Fig. 806. Lower leg fracture secured in Wittmoser's apparatus. The leg is inside the two wooden radiolucent rings which can be raised or lowered moved back and forth and sideways as required For description of this apparatus, see pages 31–34.

very satisfactory No preliminary medication (narcotics) should then be given, which might cause a dangerous lowering of the blood pressure, should spinal anesthesia fail and a general anesthesia become necessary if the procedure becomes unexpectedly protracted

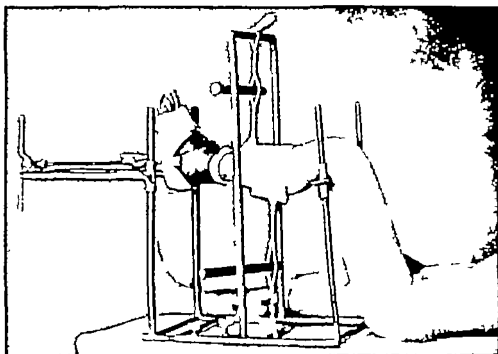


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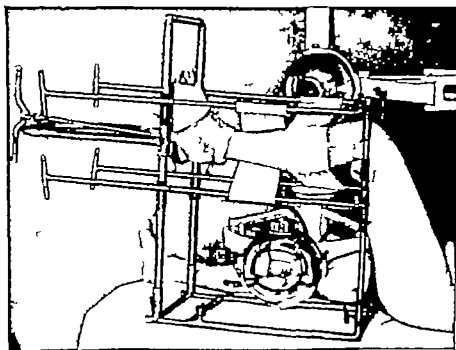


Fig. 804

Fig 804 The lower leg is firmly secured for medullary nailing by traction on the foot-hitch and by lateral straps which are tightened by the rotating double bars. The X-ray tubes are in position for fluoroscopy and roentgenography For better illustration the lateral X ray tube has been placed too high (For description of this apparatus, see pages 29–31



Figs. 812 813 Same as Figs. 809 and 810 after the insertion of a double nail after correction of recurvation and after impaction of the fragments.

Figs. 814 815 Same as Figs. 807–813 after removal of the nail and 4 months after the accident. Bony union All joints actively free. Muscles strong Still slight decalcification Got up 3 weeks after the accident without plaster cast and left the hospital on the 33rd day Resumed work after 3½ months. If this fracture had been treated with skeletal traction through the os calcis during the first 3 weeks and then with a plaster cast, the boy could have safely left the hospital after 2–3 days, without danger of bowing The fracture would have been firm in 8–10 weeks and his incapacity for work would have lasted no longer than with nailing. Medullary nailing therefore represented no worthwhile advantage over the old method.

ments are anchored in position after reduction by adequate traction straps in the four main directions (Fig 803) If the reduction apparatus of Linsmayer (Fig 805) or Böhler (Fig 804) is on hand, the traction straps are applied in that plane in which the lateral displacement and angulation are more difficult to correct which in spiral fractures is usually the sagittal plane (Fig 804) In Fig 805 these straps are applied in the frontal plane By raising and lowering the rods and by alternately turning two horizontal or two vertical rods the displacement in other planes can be corrected as well When the fragments are in good position, one may immobilize them further by 2 additional straps at right angles to the others If both ends of a strap are fastened to one rod oblique traction can be exerted in 4 directions

Reduction is most easily obtained with the 2 wooden rings of Wittmoser's apparatus (Fig 806)

Reduction is controlled by frequent momentary fluoroscopic check ups with the two X ray apparatus Sometimes the fragments are in apposition in a few minutes, but it may take one half or a whole hour

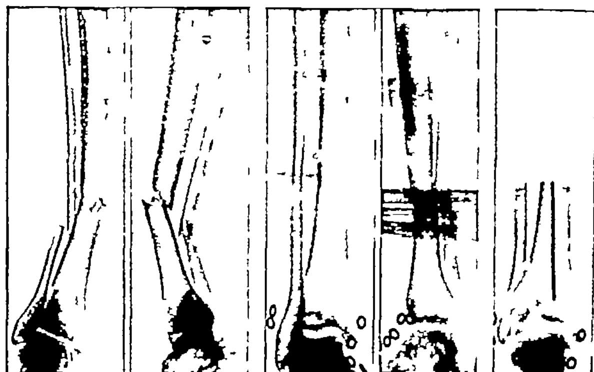


Fig. 807 Fig. 808 November 27 1942

Fig. 809 Fig. 810 November 27 1942

Fig. 811 November 27 1942

Figs. 807, 808. Leverage fracture of the right lower leg in a 17-year-old apprentice who jumped off a street car

Figs. 809 810 Same as Figs. 807 and 808, after correction of shortening, lateral displacement and angulation in Wittmoser's reduction apparatus. The fragments are distracted by 5 mm.

Fig. 811 Same as Fig. 809 after introduction of the guide pin for measuring the length of nail. The ankle joint is widened by the strong traction.

Protection against heat loss during operation To protect the patient against heat loss especially if the procedure ever becomes prolonged, we dress him carefully with a warm jacket long warm stocking a trouser for the well leg or cover him well by some other adequate means.

Application of the foot hitch A hitch is applied to the foot after adequate padding (Figs 803–806)

Positioning on the reduction apparatus The patient lies on his back. The broken leg is bent to a right angle at the hip and knee joints. The foot is fastened to the footplate by means of the hitch (Figs 803–806)

Placing of X ray apparatus The original X ray pictures, not sketches are displayed for convenient inspection and measurement during the operation a leg skeleton is on hand one X ray apparatus is placed under the flexor surface and the second opposite the medial surface of the lower leg (Fig 804)

Reduction of the fracture If the medial border of the foot is put into a vertical position the rotatory displacement of the fragments is corrected By turning the screw the shortening is overcome and by the lateral traction straps the lateral displacement and angulation are corrected If difficulty is met with the correction of the lateral displacement the fragments are first pulled apart slightly (Figs 809 810 and 819) If only an ordinary screw traction apparatus is on hand the frag



Fig. 820 Fig. 821 Fig. 822 Fig. 823
May 15 1942 September 12 1942

Figs. 820, 821 Same as Figs. 816 and 817 after 7 months. Good position and good callus. Fracture line persisting on the medial side as in Figs. I/220 221

Figs. 822, 823 Same as Figs. 816 and 817 after removal of the nail and 11 months after the accident Bony consolidation of the distal fracture at the proximal the fracture line is still noticeable on the medial side. Active motion of all joints free muscles strong. Still discomfort after prolonged walking Got up after 30 days without a cast and left the hospital after 60 days. Resumed work after 9 months. The advantage over the old methods consists in the fact that no cast was necessary and that no angulation occurred His return to work was not hastened

Application of the spring clip (Figs 76, 934 935) This is applied to protect the skin from pressure by the awl, the guide pin and the nail

Introduction of the awl The awl is bored into the bone through the small incision as nearly as possible parallel to the bone The anterior aspect of the bone is pierced 1½–2 cm distal from the transverse skin incision. As soon as one touches the posterior wall (Fig 800) the awl is withdrawn One must be particularly careful not to bore into the posterior wall otherwise the tip of the nail may get caught there and even go through the bone Until sufficient experience has been gained it is advisable to follow the route of the awl with the fluoroscope

Introduction of the guide pin For accurate determination of the required length of the nail in fractures below the middle it is best to introduce an accurately measured guide pin with rounded tip or a guide pin with centimeter markings Under fluoroscopic control it is pushed to near the ankle joint (Figs 811 876, 877) Güttner introduced this technique with us

X-ray pictures X ray pictures are now taken in both planes on films at least 40 cm in length in order to obtain an all inclusive view of the fragments and their alignment and also of the distance of the tip of the guide pin from the ankle joint



Fig. 816 Fig 817 Fig 818 Fig 819
October 8, 1941 October 8, 1941

Figs 816 817 Double fracture of the tibia and triple fracture of the fibula of left leg with overlapping and 2½ cm. shortening at the proximal fracture of the tibia. This 50-year-old ironworker riding on his motor cycle collided with a mail truck.

Fig. 818. Same as Fig. 817 after reduction and nailing. The nail bent to a right angle because it was inserted at an incorrect slant. Therefore it could not be driven further had to be retracted and replaced by a new one. The upper fragments separated as in Fig 810.

Fig. 819 Same as Fig. 816, after reduction and the driving of a new nail. It penetrates to a satisfactory depth. The lowest fragment has moved slightly laterally

To prevent *radiation injuries*, the rules given on page 37 must be observed (use of lead gloves lead aprons short exposures of 1–2 seconds) If the operation is performed in a darkened room the fluoroscopic screens are hung on the reduction apparatus so that they need not be held by hand (Figs 102, 103)

The operation must not be started until the fragments are well reduced because **perfect reduction is the absolute prerequisite for nailing and prompt healing**

Sterile draping of operative field The operator does not scrub until the fragments have been reduced and securely immobilized. The skin is then sterilized at the upper end of the leg and draped The rest of the leg must remain free for estimating the direction of the awl and the nail

Incision Medial to the tibial tuberosity a transverse incision of 2 cm is made down to the periosteum The incision must not be made above the tuberosity and enter through the patellar ligament because this tendon may slough as A W Fischer reported or even an empyema of the knee joint may develop as in the case of Stotz which ended fatally (see page 152)

ankle joint, if this happens, joint motion will be seriously impaired even if the course is aseptic and still more if an infection should cause an empyema of the joint with all its deleterious consequences (Figs 213–221 and 891–901)

Insertion of the nail from below (Figs 826, 866) We do not use this method because fractures less than 10 cm removed from the upper end of the tibia should be excluded from nailing

Skin suture and pressure bandage After the nailing has been completed, the wound is closed with 2 sutures and with a sterile pressure bandage to prevent hematoma

X ray pictures After the nail has been driven and the wound closed, X ray pictures must be taken in an exactly antero-posterior and lateral plane (Figs 812, 813, 836–851) to determine the position of the fragments and the location of the nail at the fracture site as well as at the distal end If this is omitted such incidents as pictured in Figs 213–221 might be overlooked To shorten the waiting period for these X ray pictures, a rapid developer should be used (see page 35)

Straightening the leg If the leg was not sufficiently stabilized in the reduction apparatus, a recurvation deformity will be found at the fracture site because the nail is driven in obliquely from the front to the back (Figs 146, 156) Occasionally a valgus angulation will be found (Figs 145, 155) These angulations can readily be corrected over a well padded wooden wedge (Figs 868 I, II/2488) or with a Phelps-Gocht osteoclast (Figs 91 and 934 E, I/108 and II/2746) In Figs. 157 and 158 one can notice how the gap between the fragments as seen in Figs 155 and 156 has been made to disappear by this maneuver In Figs. 150 and 158, the nail shows a forward curve at the fracture site.

Impaction of the fragments If the fragments are separated as in Figs 809 810 and 819 they must be impacted by blows with the flat hand or with the fist upon the heel (Figs 812 813), otherwise, callus formation may be delayed or a pseudarthrosis may develop as in Figs 430–441

X ray pictures After straightening and impacting, a new set of pictures should be taken in both planes because the correction might have been overdone as in Fig 148 where a recurvation was converted into an antecurvation The bending and checking with X ray pictures must be repeated until the alignment is perfect in both planes and no gaping of the fracture is present

Post-operative positioning The leg is best placed on a Braun frame The foot is suspended with a triangle cloth to prevent outward rotation (Fig II/2641) In order to recognize any rotation (Figs 227–231) immediately, the Braun frame must rest horizontally Therefore a firm bed is required (fracture boards under mattress, Figs 53 70 E I/65 I/91) In a soft bed the frame slopes and rotation of the leg can easily be overlooked

Supplementary external support If the nail was sufficiently thick and long, no additional cast or traction is needed even in spiral fractures of the lower third (Figs 836–843 and 874–883) If the nail was too short, a plaster cast must be applied and split immediately In spiral fractures treated with a nail of insufficient length and thickness shortening and angulation can be prevented only by continuous traction

A film as short as in Fig 811 is not satisfactory The central ray must be directed through the ankle joint to prevent a distorted projection of the location of the tip possibly making it appear closer to the joint than it actually is The distance between the tip of the guide pin and the ankle joint line is measured as well as the length of that part of the pin which protrudes beyond the skin incision. The nail must be chosen 3 cm shorter than the distance between the skin incision and the ankle joint line because the nail should reach to within 1 cm of this line and 2 cm. of its upper end should be covered with skin

Driving the nail from above After removal of the guide pin, a bifurcated nail is usually driven in It must be held as flatly as possible against the knee so that it



Fig 824 Fig. 825 Fig 826 Fig. 827

October 29 1941 October 29 1941

Figs. 824 825 *Compound* comminuted fracture below the tibial head and separation of the proximal tibio-fibular joint on left leg Also extensive soft tissue wounds, exposure of the knee joint, thrombosis of the popliteal artery in a 43 year-old woman postal-clerk whose leg was caught between a heavy package and a railroad car Wound excision under local anesthesia and medullary nailing from below

Figs. 826, 827 Same as Figs. 824 and 825 after medullary nailing The fragments are in good apposition. The thrombosis caused gangrene of the toes on the next day and the leg had to be amputated. Fractures so close to the knee joint are not suited for medullary nailing even if they are closed fractures and not comminuted.

will not get caught on the posterior wall Since the tip of the nail is oblique, it bounces off the posterior wall towards the anterior wall along which it continues its path (Fig 802) If it is inserted too steeply it may bend to a right angle (Fig 818) and become stuck. As soon as it approaches the fracture its position is checked by biplane fluoroscopy If it shows a tendency to leave the medullary canal, the distal fragment must be moved accordingly 2–3 mm parallel towards the direction in which the nail threatens to protrude (Fig 204) and in addition to this, the distal fragment must be angulated several degrees in the same direction Then the nail is driven into the distal fragment When it approaches the ankle joint, the central rays of both X ray machines must be directed through the ankle joint and great care must be exercised by fluoroscopic control that the point does not enter into the

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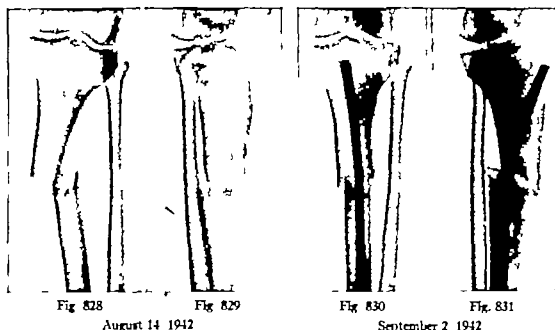


Fig 828 Fig 829 Fig 830 Fig. 831

August 14 1942 September 2 1942

Figs. 828 829 Transverse fracture of the left tibia in the upper third and dislocation of the head of the fibula in a 44-year-old railroad worker who was caught between two locomotives. Also burns of the calf the thigh and the buttocks.

Figs. 830, 831 Same as Figs. 828 and 829 after medullary nailing The distal fragment is displaced posteriorally because the shortening was not completely corrected before the operation. A fragment chipped off posteriorally is interposed between the fragments. These fractures are not well suited for medullary nailing.

Exercises The toes must be exercised within the range of comfort from the first day on During the second week active exercises of the ankle knee and hip can be started If the nail is well seated and if no complications arise, all joints of the leg show normal range of motion during the third week

The old fact that *vigorous massage and forcible passive motion* are most detrimental in the treatment of all fresh and even most old injuries (see page I/37) holds equally true for medullary nailing It can accomplish only an irritation of the tissues and a redisplacement of the fragments

The rule **exercises must never cause pain** (see page I/31) must likewise be observed after medullary nailing

Infection In 67 closed medullary nailings of the lower leg an infection of the fracture developed in the last one requiring amputation of the leg (see pages 150, 151) Twice inflammation occurred at the nailing site which subsided after removal of the sutures

Subsequent course Marked swelling with bleb formation occurs very seldom after medullary nailing Edema of the ankle after getting up and decalcification are as a rule slight, if the indication and technique were correct.

Patients with transverse fractures of the tibia only (Figs 121–132) may get up without additional support after one week For these fractures the nail is most valuable because they frequently develop angulation (Figs. II/2480–2487) when



Fig 832 Fig 833 Fig 834 Fig 835

January 3 1943 July 5 1943

Figs 832, 833 Same as Figs 828 831 after 4½ months Callus formation is delayed the fracture line is still open because the fragments are prevented by the curved nail from approximating

Figs 834 835 Same as Figs 828–831 after extraction of the nail and 11 months after injury Bony consolidation The nail track is plainly visible

treated with a cast and are apt to show slow union (Figs II/2472–2479) Patients with oblique or spiral fractures should remain recumbent for 3 weeks For earlier ambulation a walking cast must be applied If this is done the nailing offers no advantage over traction followed by cast For fractures above the middle a circular plaster cuff from the ankle to the hip is sufficient For fractures below the middle a short plaster cuff from the knee to the ankle is ineffective (Figs 205 206) In fractures below the middle, if the nail does not reach into the immediate vicinity of the ankle joint as in Figs 874–883 a walking cast must be used for six weeks

Delayed callus formation Insufficient impaction of the fragments may retard callus formation and lead to pseudarthrosis (Figs 430–441) since both the fibula and the medullary nail prevent an approximation of the tibial fragments The bend in the nail prevents the fragments from sliding, and thus approximating under weight bearing

Osteotomy of the fibula If it is evident after 6 weeks that callus formation is insufficient it is best to osteotomize the fibula transversely thus eliminating its locking effect

Hospital stay Some cases with favorably located transverse fractures of the tibia alone may leave the hospital in the second week, others during the third or fourth week

Duration of treatment In the beginning the average period of treatment was not shortened but prolonged because 2 cases developed a pseudarthrosis (Figs 430–459) and because angulations developed from the use of too short and too thin nails (Figs

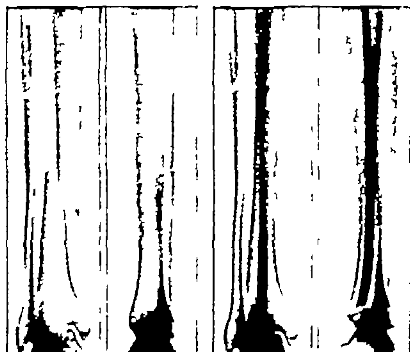


Fig. 836 Fig. 83 Fig. 838 Fig. 839
November 24 1942 November 24 1942

Figs. 836, 837 Spiral fracture of the tibia between the middle and lower third and of the fibula in the proximal third in a 40-year-old man who slipped on an icy street

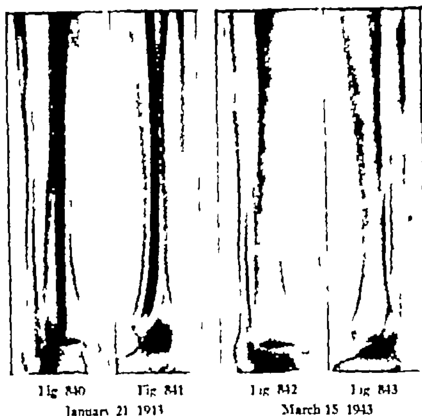
Figs. 838 839 Same as Figs. 836 and 837 after medullary nailing The fragments are in accurate apposition. Started to walk after 20 days without a cast and left the hospital after 26 days.

202–212) Since we have overcome the initial difficulties by using nails of proper length and thickness and by thoroughly impacting the fragments the duration of treatment is sometimes shorter than in unnailed cases

Further supervision After discharge from the hospital the patient returns for a check up every 1–2 weeks. X ray control pictures are taken every 4 weeks to detect any possible angulations or disturbances in the callus formation in time Once patients have been permitted to resume work, they must report every 2 months for an X ray check-up until the nail is extracted In order not to lose track of them a special file is kept for such nailed cases (see page 54)

Extraction of the nail The nail must not be removed until X ray pictures show bony consolidation The nail in the bone obstructs a clear view of the callus formation and therefore the fracture is often considered firmly united at too early a date as in Figs 450 451 If the nail is then removed prematurely angulations (Fig 211) or non union (Figs 452–455) may ensue At least 6 months should elapse On the other hand, the nail should not be left in too long because corrosion is apt to develop at the juncture of the blades in double nails

If 6 months have elapsed extraction is usually easy under local anesthesia. Formerly we performed this in the outpatient department It is preferable, however to admit the patients for a few days to avoid wound disturbances. The



Figs 840, 841 Same as Figs 836–839 after 2 months. Good callus formation No redisplacement because the double nail was sufficiently thick and long

Figs 842, 843 Same as Figs 836–839 after 4 months and 1 month after removal of the medullary nail. A slight varus angulation developed because the nail was removed too soon. If traction had been used for 3 weeks followed by a walking cast this patient would also have been able to walk on the 22nd day and could have left the hospital on the 26th day

extractor of Küntscher (Fig 71) or of Pohl or of Stör (Fig 83) and the forceps of Jörg Böhler (Fig 84) must always be ready If the nail has been driven in so deeply that it does not protrude beyond the bone it is difficult to find The wire net of Jeschke (Fig 180) is of great use in this case

Incidents during closed medullary nailing of the lower leg Untoward incidents which may arise during medullary nailing have been discussed on pages 72–89 Fatalities due to operating under shock are comparatively rare in leg fractures as compared to femoral fractures. Most incidents are due to lack of the necessary apparatus and instruments such as a reduction apparatus, 2 X ray machines, sufficient selection of nails extractors etc

Incidents due to the use of too thick a nail (Figs 153–160) can more readily be overcome on the lower leg than on the femur If the nail cannot be extracted and no steel saw (Fig 70) is on hand, the comparatively thin nail can be snipped with a pair of strong cutting pliers

If the reduction was not critical the nail may protrude at the fracture (Fig 204) It can be retracted easily in contrast to the femur If a double nail is used, the thin blade may protrude posteriorly the heavier blade anteriorly If the former happens (Figs 852–855), no difficulty will arise and the condition may be left unchanged until



Figs. 844 845 Leverage fracture of both bones of the right lower leg in a 47-year-old man who was knocked down by an automobile.

Figs. 846, 847 Same as Figs. 844 and 845 after medullary nailing. Fragments in good apposition. The nail is slightly too short, but sufficiently heavy Got up with a cast after 3 weeks and left the hospital after 4 weeks.

the fracture unites If the nail protrudes anteriorly it may perforate the skin as I have seen happen on one occasion It was removed immediately from below without difficulty The thinner of the two nails had penetrated into the distal fragment and alone provided sufficient hold because only the tibia had been fractured

Especially severe and prolonged disturbances developed in the compound fracture of Figs 430–441 In this instance the traction used after wound excision and skin suture was too strong causing a hiatus between the fragments of the tibia and fibula with a lateral displacement and a valgus angulation of the tibia (Fig 432) The insertion of the nail was therefore extremely difficult This could have been avoided if the lateral displacement and angulation had been corrected completely and the traction released before the introduction of the nail The gaping fracture of the fibula healed after a few months (Figs. 434 435) but the tibia could not unite because of the double locking action of the fibula and the bent nail. Weight bearing caused a fatigue fracture of the nail. The tibia did not unite until the nail was removed and a portion of the fibula was resected (Figs 440 441)

Advantages and Disadvantages of Küntscher's Closed Medullary Nailing as Compared with Other Methods

If suitable cases are carefully selected (see indications and contra-indications on pages 248–250) and the operation is performed at the right time (not during



Fig. 848 Fig. 849 Fig. 850 Fig. 851
April 3 1942 February 15 1943

Figs 848 849 Same as Figs. 844–847 after 3 months. Good callus formation posteriorly No angulation or shortening occurred as in Figs. 202–212 because a walking cast was applied before he started to walk and was left for 6 weeks.

Figs. 850 851 Same as Figs. 844–847 after extraction of the nail and 13 months after the injury Healed in good position. Bony consolidation. All joints actively free. No discomfort. If traction had been used for 2–3 weeks followed by a walking cast, he would also have been able to walk after 3 weeks and to go home in the 4th week.

shock with marked swelling with open wounds or with skin diseases) and with correct technique (exact reduction before nailing, correct choice of nail) the results are sometimes better than with the use of continuous traction and plaster cast. Callus formation is not more rapid The local circulatory disturbances however, are less pronounced, therefore, the wasting of muscles and decalcification of bones are not so marked In those cases which need no supplementary support, free motion is maintained. In transverse fractures of the middle, the hospital stay is shorter and the end results are better On the other hand it must be emphasized that the number of possible complications is great and, if infection sets in, it may even lead to amputation (see pages 150, 151), so that healing may be greatly delayed through minor technical errors **Therefore the indication for medullary nailing of the lower leg must be weighed very carefully**

Causes of Failure in Closed Medullary Nailing of the Lower Leg

1 **Operation under shock This may cause death** Medullary nailing is no emergency measure

2 Operating in the presence of swelling and fever Medullary nailing is no emergency measure

3 Operating in the presence of deep abrasions over the tibia This may cause infection of the fracture.

4 Operating in the presence of open wounds on other parts of the body (i.e., before 2–3 weeks have elapsed, if the operation was impossible within the first few hours) Medullary nailing is not an emergency measure.

5 Operating in the presence of blebs

6 Operating in fractures extending into a joint

7 Operating in fractures less than 10 cm removed from the joints

8 Operating without necessary equipment (selection of nails extractors, etc)



Fig 852 Fig. 853 Fig. 854 Fig 855

April 15 1942 October 23 1942

Figs. 852, 853. Spiral fracture of the middle third of the tibia and upper third of the fibula in a 42 year-old carpenter with peroneal paralysis and decalcified bones. Medullary nailing with double nail. The thinner nail slipped out between the fragments during the driving and lies on the lateral and posterior side of the tibia. The heavier nail is in good position and is thick and long enough.

Figs. 854 855 Same as Figs. 852 and 853 after removal of the nails. Bony union in good position.

9 Operating without reduction apparatus

10 Operating with one instead of two X ray machines.

11 Failure to use local anesthesia for the X ray pictures Without it, the leg cannot be positioned properly for a strictly lateral view

12 Neglect to determine accurately the length, width and curve of the medullary canal.

13 Neglect to protect the patient against heat loss.

14 *Failure to reduce the fragments accurately*

15 Neglect to use a guide pin for measuring in fractures below the middle

16 Neglect to use the fluoroscope when inserting the guide pin
17 Failure to check the position of the guide pin after its insertion by an X ray picture focussed over the ankle joint
18 Neglect to use the fluoroscope during the driving of the nail
19 Fluoroscopy without lead gloves and lead apron
20 Failure to take X ray pictures of sufficient size and focussed over the ankle joint, after the insertion of the nail
21 Neglect to straighten the leg if the angulations persist
22 Failure to impact the fractures
23 Positioning on a bed without firm support, because one may thereby overlook rotation
24 Use of vigorous massage and forcible passive motion
25 Getting up without additional plaster cast, if the nail in fractures below the middle did not reach to within the immediate vicinity of the ankle joint
26 Neglect to continue observation of the patient with X ray check ups until the fracture is firm and the nail has been removed
27 Failure to keep a special file on nailed fractures
28 Premature removal of the nail
29 Failure to take X ray pictures at the conclusion of the treatment

Closed Medullary Nailing of Old Fractures of the Lower Leg

In old fractures with angulation or with delayed callus formation, closed medullary nailing can after correction of the deformity sometimes be carried out even 2-3 months later This is always to be preferred to open nailing because with correct technique the danger of infection is at a minimum

In a fracture of the proximal third as in Figs 244-251, the operation must be followed by a plaster cast from the ankle to the hip because the nail does not provide sufficient stability Since this was omitted in this case the nail migrated (Fig 248) and permitted angulation (Fig 250) Both these complications could have been prevented by a supplementary plaster cast If in this case the tibia had been merely straightened and a plaster cast from the ankle to the hip had been applied instead of using a medullary nail the fracture would have healed without angulation In other words a better result could have been obtained by a much simpler and less dangerous procedure In isolated fractures of the tibia callus formation is greatly stimulated by gently fracturing the fibula with a Phelps-Gocht osteoclast (Fig II/2456) because this permits an approximation of the fragments But even in old fractures of both bones union is enhanced by vigorous bending before nailing This also facilitates the correction of lateral displacement

Rejection of Open Medullary Nailing in Fresh Closed Fractures of the Lower Leg

With our reduction apparatus (Figs. 803-806) we have always succeeded in satisfactorily reducing the fragments in closed leg fractures for medullary nailing



Fig. 856 Fig 857 Fig 858 Fig 859
October 7 1941 October 7 1941

Figs. 856, 857 *Compound* fragmented fracture of the right tibia with 3 cm. intermediate fragment and fracture of the fibula, in a 39 year-old mason who was struck by an automobile while riding his motorcycle. Also fracture of the right femur fracture of the head of the left tibia, two large contused lacerations of the head and contusion of the chest. Wound excision and debridement of the soiled intermediate fragment from which the periosteum had to be removed so that it was entirely disconnected. Insertion of the intermediate piece and medullary nailing (Dr Korn, Dr Linsmayer) Medullary nailing of the femur Braun splint. We no longer nail such compound fractures with an intermediate fragment because it may sequestrate and osteomyelitis may supervene.

Figs. 858 859 Same as Figs. 856 and 857 after nailing The intermediate piece was threaded upon the nail and is in good apposition Rubber drain shows plainly A skin necrosis and sinus formed over the intermediate piece without inflammation or elevation of temperature.

In the exceptional case where the fragments cannot be reduced exposure of the fracture should be omitted entirely because by so doing the greatest advantage of Küntscher s method in closed fractures is lost, namely that only a small wound is made at a distance from the fracture Such cases should be treated with skeletal traction or a plaster cast. The dangers of the old methods of osteosynthesis of fresh closed fractures involving exposure of the fragments are described on pages I/152 153 These risks are still greater with medullary nailing

Rejection of Open Medullary Nailing in Fresh Compound Fractures of the Lower Leg

The danger of infection is greater in all compound fractures since the fragments were exposed by the trauma. Infection may lead to loss of life loss of the leg or



Fig 860 Fig 861 Fig. 862 Fig 863

January 14 1942 January 5 1943

Figs. 860 861 Same as Figs. 856–859 after 3 months. Antero-medially a part of the intermediate piece begins to separate

Figs. 862, 863 Same as Figs 856–859 after 15 months, and 5 months after removal of the nail and of a 3 x 2 cm sequestrum. Bony union of tibia in good position all joints free. Walks well. The healing process took an unusually favorable course in this case since only part of the intermediate piece sequestrated. Such tubular fragments usually sequestrate in toto after open nailing causing defect pseudarthrosis. Such fractures should therefore not be treated with open medullary nailing

to the loss of full function When considering medullary nailing the question must be answered whether these dangers are increased or decreased by its use After a thorough study of our own cases and of many treated elsewhere, I must state that the number of serious infections following medullary nailing of compound leg fractures is much greater than it was before its use (Figs 213–220, 864–873 884–893, 894–901 and 910–915) although many cases took a favorable course (Figs 143–152, 856–863 874–883) Even if an aseptic healing ensues, a delay of callus formation (Figs 202–212 430–441 442–459) is common and the average duration of treatment is much longer than in non nailed cases

When I returned from field service in 1941 for several months' stay at home, I found that enthusiasm for medullary nailing had in many localities risen to such a high pitch that compound fractures of the lower leg were frequently nailed without due regard for the general condition the age the wounds and the location of the fracture (Figs 894–901) In addition to faulty indication, the technique left much to be desired in many cases as shown in Figs 213–221 and 430–441 I therefore



Fig 864 Fig. 865 Fig 866 Fig 867

March 17 1943 September 29 1943

Figs. 864 865 *Compound* leverage fracture of the left leg with comminution for a distance of 14 cm. and marked soft tissue crush, in a 31 year-old mechanic whose leg was caught between a tractor and its trailer Thorough wound excision one hour later and medullary nailing from the distal fragment, as in Fig. 826. The wedge fragment was fastened with a wire suture. Such compound comminuted fractures should not be nailed

Figs. 866, 867 Same as Figs. 864 and 865 after 6½ months. The seriously damaged skin became necrotic and infection of the entire wound ensued. The wedge fragment and numerous other fragments sequestrated, producing a defect pseudarthrosis of the tibia Areas of bone absorption and sequestra can be seen in the distal fragment.

gave orders at that time to exclude the following compound leg fractures from medullary nailing

1 All cases in profound shock as usually seen in multiple injuries.
2 All cases with seriously damaged skin (contusion extensive abrasions, burns, skin defects) because skin necrosis may lead to infection of the medullary canal and to sequestration (Figs. 213–221 and 864–873)
3 All fractures less than 8 cm removed from the knee or ankle joint, because the nail does not provide sufficient stability in fractures near joints (Figs. 169–178, 213–221 824–827 and 894–901)
4 All splintered comminuted and fragmented fractures even if the skin is in comparatively good condition (Figs 856–863 864–873 884–893)

In 15 fresh compound lower leg fractures during 1941, 5 cases developed infection which was severe in 4 of these



Fig. 868 Fig. 869 Fig. 870 Fig. 871 Fig. 872 Fig. 873

November 10 1943 December 3 1943 January 9 1945

Figs. 868 869 Same as Figs. 864 and 865 after removal of the nail. The hiatus in the tibia has narrowed. Three medullary sequestra are lying in the distal fragment.

Figs. 870 871 Same as Figs 864 and 865 after 9 months. The sequestra at the fracture site and the medullary sequestra are removed The latter required saucerizing the distal fragment. Two weeks later cloudy serous inflammation of the knee joint which subsided 3 weeks later after 2 aspirations. Was discharged from the hospital with a walking cast 11 months after injury

Figs 872, 873 Same as Figs. 864 and 865 after 22 months and 13 months after removal of the sequestra. No resiliency at fracture site which begins to be bridged. Wound epithelialized except for a 1 x 2 cm. area. Without medullary nailing such massive sequestra would probably not have formed and definitely no medullary sequestra. The treatment would have been shorter and the end result better

In the case of Figs 169–178 a sinus developed at the nailing site, which closed after extraction of the nail This fracture was close to the joint and was splintered It should not have been nailed because the nail could not provide sufficient stability

The case of Figs 213–221 should not have been nailed because the fracture was too close to the ankle joint. The infection permitted the nail to plow into the ankle joint which became infected and ankylosed.

In Figs 894–901 the fracture was so close to the ankle joint that the nail could not immobilize it The skin was so severely damaged that it became necrotic, leading 10 days later to infection of the fracture site and of the ankle joint Besides the skin condition the proximity of the joints the age and the poor general condition of the patient constituted a contra indication against medullary nailing in this case



Fig. 874 Fig 875 Fig 876 Fig 877
November 27 1942 November 27 1942

Figs. 874 875 *Compound* spiral fracture of the lower third of the left tibia and closed spiral fracture of the upper third of the fibula, in a 41 year-old mechanic whose trousers were caught by a revolving shaft. Wound excision under spinal anesthesia. We no longer nail such compound spiral fractures, but unite the fragments with 2 circumferential wire loops, as in Figs. 904 and 905

Figs. 876 877 Same as Figs. 874 and 875 after wound excision. Both fragments are held in exact apposition with a Lambotte clamp and a blunt guide pin is introduced for measuring the length of the required nail. After nailing and insertion of a drain, the wound was closed and a dorsal plaster splint was applied. Wound healed without complications.

The remaining 2 cases were shaft fractures with marked comminution and skin damage These too should therefore not have been nailed

The result of my instructions for stricter indication was that during the year 1942 15 out of 16 cases of fresh compound leg fractures healed without wound complications purulent infection developed in only one comminuted fracture near the ankle joint In this case points # 3 and # 4 of my instructions (see page 270) were disregarded

In 1943 serious infections developed in 4 cases out of 14 fresh compound lower leg fractures which had been treated with medullary nailing

Case 1 The 31 year-old mechanic s helper of Figs. 864–873 was admitted on March 17 1943 one hour after the accident the wound was excised and medullary nailing was performed although the bone was comminuted for a distance of 14 cm. and large skin and muscle wounds were present. The nailing was very difficult and was only accomplished after four attempts, during which the large fragment on the anterior surface was completely ejected. After 6 days an inflammation developed requiring several incisions. During the subsequent months many fragments separated leaving a large defect in the tibia (Figs. 866 867) After removal of the nail which was carried out much too late 3 large sequestra can be seen in the medullary cavity (Figs. 868 869) These could

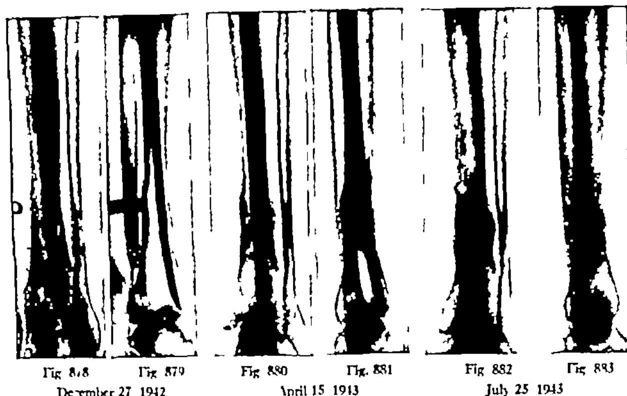


Fig 878 Fig 879 Fig 880 Fig. 881 Fig 882 Fig 883

December 27 1942 April 15 1943 July 25 1943

Figs. 878 879 Same as Figs. 874–877 after nailing and insertion of drain. The nail reaches along the anterior wall to within 6 mm. of the ankle joint. The position remains good. Got up after 7 weeks with an Unna boot.

Figs. 880 881 Same as Figs. 874–877 after 4½ months. Bony union in good position.

Figs. 882 883 Same as Figs. 874–877 3 months after removal of the nail and 8 months after injury Good position. Bony consolidation Resumed work after 5 months. All joints actively free No com plaints. If instead of the nail 2 circular wire loops had been used as in Figs. 904 and 905 followed by a walking cast 3 weeks later he would have been able to get up in the 4th week instead of in the 8th week.

be removed only by chiseling away the anterior wall of the tibia (Figs. 870 871) After 14 days, erysipelas developed followed by a cloudy serous effusion in the knee joint which subsided in the course of 3 weeks after 2 aspirations. The patient was in the hospital for 11 months A sinus was still open after 22 months and the fracture was still loose requiring a cast Without medullary nailing osteomyelitis with medullary sequestra and the separation of such large cortical sequestra would not have occurred and the fracture would have united much sooner

Case 2 A 44-year-old blacksmith suffered a compound comminuted fracture of the lower leg with extensive skin injuries on May 11 1943 from the explosion of a barrel (Figs. 884 885) Two hours after the accident the wound was thoroughly excised and the tibia was nailed It was possible to close the skin after 2 relaxation incisions had been made These incisions were then covered with Reverdin skin grafts. The wounds healed uneventfully Six weeks later the patient was discharged from the hospital with a walking cast X ray pictures showed no trace of callus (Figs 886 887) 11 weeks later Therefore resection of the fibula was done and a new walking cast applied which was followed by a narrowing of the fracture line (Figs. 888 889) On Oct. 29 1943 i.e., almost 6 months later in the midst of the best of health the patient was seized with severe pain in the lower leg and chills. On admission a few hours later the leg showed swelling redness and heat when the cast was removed. Two days later an abscess showed at the nailing site and another one at the fracture site. Both were incised and the nail was removed whereupon the tem perature subsided. Ten weeks later the sinus was still draining at the fracture site and rarefied areas were evident in the medullary canal but no sequestra were present (Figs 890 891) The cast



Fig. 884 *Fig. 885* *Fig. 886* *Fig. 887*

May 11 1943 July 30, 1943

Figs. 884 885 *Compound* comminuted fracture of the right leg with marked displacement of the intermediate fragment and moderate skin damage, in a 44-year-old locksmith from explosion of an oil barrel. Two hours after injury thorough debridement and medullary nailing Since the skin could not be closed, two relaxation incisions were made which were covered with Reverdin skin grafts. Wounds healed without disturbances.

Figs. 886, 887 Same as Figs. 884 and 885 after 11 weeks. Good position of the fragments. Marked decalcification of the distal end of the tibia and fibula, especially at the epiphyseal line. No trace of callus formation because the curved heavy nail prevents the approximation of the fragments. Therefore resection of the fibula.

was removed on Feb. 10 1944 The fracture was clinically firm The fracture showed bony union in good position 13 months after the accident, but a sinus persisted and the patient needed a cane for walking After 18 months the sinus closed.

Case 3 A 62 year-old cab-driver was kicked by a horse on July 8 1943 suffering a compound fracture in the middle of the lower leg with comminution of the tibia for 8 cm. The skin wound was 5 cm. long Thorough debridement three hours after the accident. Because of the comminution the nailing was very difficult Since the nail did not provide sufficient stability a supplementary wire suture was applied The skin over the fracture could not be closed until 2 large relaxation incisions had been made which were covered with Reverdin skin grafts. A fenestrated cast was applied. After 3 days, fever was noted and after 8 days suppuration Part of the transposed skin became necrotic and separated, which was followed by high temperature and marked suppuration. Because of continuing high temperature and the large skin defect, the leg was amputated above the knee on Sept. 3 After this the temperature quickly returned to normal and the patient recovered.

Case 4 The 16-year-old apprentice of Figs. 910–915 was knocked off his bicycle by a truck on Oct. 25 1943 and run over He suffered a compound fracture of the lower leg (Figs. 910 911) with



Fig. 888 Fig. 889 Fig. 890 Fig. 891 Fig. 892 Fig. 893
October 18 1943 January 10 1944 April 15 1944

Figs. 888, 889 Same as Figs. 884–887 three months after resection of the fibula. Fracture line narrower The gap in the fibula begins to fill. Decalcification increased. Six weeks later sudden acute osteomyelitis without external cause.

Figs. 890 891 Same as Figs. 888 and 889 eleven weeks after removal of the medullary nail. Fracture line again somewhat wider In the A P view osteomyelitic cavities without sequestra can be seen in the distal fragment and in the lateral view in the proximal fragment. The gap in the fibula is bridged on the medial side by periosteal callus.

Figs. 892 893 Same as Figs. 884 and 885 after 11 months. The fracture line is bridged but not consolidated. Calcium content increased. The plaster cast was removed 9 months after injury Still walks with a cane. If in this case skeletal traction through the os calcis had been used after thorough excision a fenestrated unpadded cast applied and continuous traction used as in Figs. 869 E II/2509 the fracture would probably have united sufficiently for weight bearing in 3–4 months and no osteomyelitis with persistent sinus formation would have developed. Resection of the fibula would not have become necessary Wire suture could also have been used.

extensive soft tissue injury On the medial side of the leg there was a gaping transverse contused laceration, 15 cm long and 5 cm. wide, from which the torn muscles protruded The proximal fragment of the tibia was exposed The skin on the inner side of the leg was severely crushed and blue. Over the fracture of the fibula there was a small skin wound of 3 x 3 cm. punctured from within. No damage was evident to the nerve and blood supply Debridement under local anesthesia followed 1 hour after the injury In order to reach all the torn muscles a 12 cm. incision was made along the tibia towards the ankle. The soiled bone was cleaned with a rongeur The wedge fragment of the fibula was removed to create a gap Then nailing of the tibia was easily accomplished and a wire suture was applied (Figs. 912 913) Three drains were inserted and the skin closed as far as this was possible without tension. The plaster cast was split and fenestrated immediately The remaining large skin defect was covered with 170 Reverdin skin grafts. Wound healing took place without gross disturbances The severely contused skin became dry and black during the subsequent days



Fig 894 Fig. 895 Fig 896 Fig 897
December 15 1941 December 15 1941

Figs. 894 895 *Compound* fracture of the tibia in the lower third and a double fracture of the fibula in a 66-year-old workman who was buried under building debris On the posterior aspect of the leg an 8 cm wound through which the badly soiled tibia protrudes for 4 cm Wound excision under spinal anesthesia. Figs. 896, 897 Same as Figs. 894 and 895 after the insertion of a double nail. The two nails were spread apart for better hold upon the bone The fragments are not in accurate apposition A wire loop or calcaneal traction would have been better

Nov. 14 Scarlet fever developed and necessitated transfer to the contagious ward where he became afebrile after a few days.

Dec. 17 After return from the contagious ward the general condition was good and the cast was removed revealing a good take of the skin grafts. In the area of the contused and necrotic skin outside the fracture, a clean wound of 8 x 12 cm. was seen. No fever or pain. The fragments were in good position No inflammation or suppuration was present at nailing or fracture site.

Jan. 1 1944 Sudden chill and temperature of 40.2°C. Pain and redness at the fracture and nailing sites. Two days later suppuration at both places Septic temperatures after Jan. 7 then afebrile.

Jan. 10 Extraction of the nail. Afebrile.

March 9 Removal of wire suture because it lay exposed in the wound.

May 4 Removal of cast Fracture clinically firm, sinus still persisting

Nov. 22 Leg still swollen sinus closed.

Since no wound complications had been encountered for some time, the 4 instructions of page 270 had been forgotten All were anxious to do as many medullary nailings as possible and insufficiently experienced men performed it even in the presence of serious soft tissue and bone damage The absence of early infection in the cases shown in Figs 884–887 and 910–915 emboldened them Since such late infections of the medullary canal have to my knowledge not been reported to date, I have reported them in detail.

A comparison of our results obtained in fresh compound leg fractures with medullary nailing and those obtained without nailing (see Figs. I/160–169 and II/2512–2541) proves that the new method has several disadvantages when used in this type of injury



Fig. 898 Fig. 899 Fig. 900 Fig. 901
April 23 1942 January 11 1943

Figs. 898, 899 Same as Figs 894–897 after 4 months. Skin necrosis developed after the accident. After 10 days inflammation of the fracture site and of the ankle joint; the 2 points of the nail penetrated into the astragalus which had become softened by the inflammation. Marked decalcification.

Figs. 900, 901 Same as Figs 894–897 after 13 months. Bony union in good alignment. Ankylosis of the ankle joint. Calcium content somewhat increased. The arrow points to a sequestrum. Gait greatly impaired. A sinus was still draining after 2½ years. Without medullary nailing the purulent infection of the ankle joint with its serious sequelae would probably not have occurred.

Serious infection is reported by Ehalt in his book in 7 cases (6 2%) out of 117 compound fractures of the leg and in 2 cases (6 7%) out of 29 isolated compound fractures of the tibia. Out of 46 nailed fractures serious infection occurred in 10 cases (21 7%) which is more than 3 times as frequent. Furthermore infection is much more serious in nailed cases because the inflammation affects not merely the fracture and the soft tissues but the entire medullary canal

Osteomyelitis never followed the previous methods of treatment. Now we find, in addition to sequestra at the fractured ends, sequestra also in the medullary cavity as in Figs 219 and 864–873. We do not know whether such sequestra may not have developed later in the other cases

Joint empyema of the knee and ankle has never occurred before unless the joint itself was exposed by the injury. In the 46 nailed cases purulent arthritis occurred twice in the ankle joint and an inflammation of the knee joint occurred once

Permanent sinuses never resulted before. In nailed cases they were still open after two years and we do not know when they will close, if at all

Pseudarthrosis never developed before in aseptic cases; now several occurred (Figs. 430–441 and 442–459)

Duration of treatment. In cases that have been concluded to date, the duration of treatment is much longer than before nailing was used, even in aseptic cases

Open nailing in fresh compound fractures prohibited. Since medullary

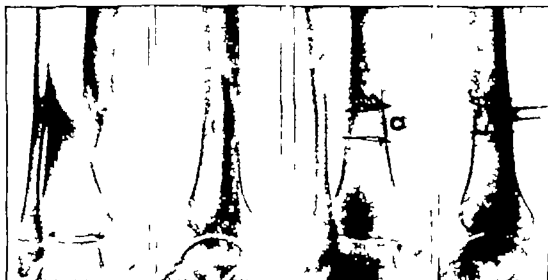


Fig. 902 Fig. 903 Fig. 904 Fig. 905

November 4 1943 November 4 1943

Figs. 902 903 *Compound* oblique fracture of the right leg in the lower third and compound fracture of the internal malleolus with marked displacement The 24-year-old blacksmith was struck in the leg by a large piece of iron which flew out of a pneumatic press.

Figs. 904 905 Same as Figs 902 and 903 After accurate excision of both wounds under local anesthesia, the 3 fragments were grasped with a Lambotte clamp and united with 2 circumferential wire sutures. The internal malleolus was fastened after reduction with 4 periosteal sutures. The wounds healed without disturbance. After 18 days a walking cast was applied, with which the patient left the hospital one week later

nailing of fresh compound fractures of the lower leg is extremely dangerous and offers no worthwhile advantages but on the contrary usually entails disadvantages, I have prohibited it in my jurisdiction While still under the influence of the good results obtained in 1942 I wrote on page II/1265 that we are nailing compound fractures of the lower leg

Wire suture in fresh compound leg fractures On page II/1265 I recommended wire suture for those cases in which the fragments are displaced and press against the damaged skin possibly causing necrosis of the skin, which may in turn cause secondary infection This displacement can be prevented by a wire suture The suture technique is simple and with experience does not consume much time It should be used only by those who have practiced it before on pieces of wooden rods cut obliquely and transversely Figures 902–909 and 916–921 show the results of this procedure If infection develops in spite of the suture, only a localized osteitis confined to the fracture area will develop never an osteomyelitis

Wired leg fractures must be kept under careful observation In oblique and spiral fractures between the middle and distal third bony union follows the wiring with comparative rapidity If the wires are not removed after 3–4 months a ring shaped (circular) area of bone absorption occurs which becomes deeper and deeper, leading to a transverse pseudarthrosis as in Figs 908 909 This type of pseudar



Fig. 906 Fig. 907 Fig. 908 Fig. 909

January 18 1944 May 6 1944

Figs. 906, 907 Same as Figs. 902–905 after 11 weeks. Periosteal callus on the lateral and posterior sides. Fracture line widened

Figs. 908 909 Same as Figs 902–905 after 6 months. The periosteal callus on the posterior and outer side has become stronger but does not touch the cortex at the fracture site. Laterally above, the fracture line is obliterated medially below It has become wider giving the appearance of a beginning pseudarthrosis. At the upper wire loop a wide ring of bone absorption is visible The wires were removed and 6 weeks later the fracture line obliterated. The fracture of the internal malleolus shows bony union in good position.

throsis may also follow the use of the Parham Putti band in this region In other areas of the tibia such changes are rare

Open Medullary Nailing of Fresh Gunshot Fractures of the Lower Leg

In contrast to gunshot fractures of the femur it is comparatively easy to immobilize gunshot fractures of the lower leg by a plaster cast In view of poor experiences with the nailing of fresh compound fractures of the lower leg its use in gunshot fractures should also be rejected

Open Medullary Nailing of Infected Gunshot Fractures of the Lower Leg

The nailing of infected gunshot fractures of the lower leg must be rejected because its use spreads the infection and leads to the formation of additional sequestra If immobilization in plaster alone should be inadequate a double wire transfixion cast may be used (Figs II/2434–2449) but great care must then be exercised to avoid distracting the fragments, otherwise callus formation will be retarded and pseudarthrosis may follow as with the use of excessive weight in continuous traction (Figs 358–365)



Fig 910 Fig 911 Fig 912 Fig 913 Fig 914 Fig 915

October 25 1943 November 12 1943 April 12 1944

Figs. 910 911 *Compound* leverage fracture of the right leg between middle and proximal third A small cuneiform fragment is still in contact with the distal fragment in a 16-year-old apprentice who was knocked off his bicycle by a truck and run over Extensive skin and soft tissue wounds were excised under local anesthesia one half hour after injury and partly sutured. The large skin defect was covered with 170 Reverdin grafts.

Figs 912 913 Same as Figs. 910 and 911 after 3 weeks, with tibial fragments in good apposition, held by a medullary nail and a loop of wire After 10 weeks, sudden osteomyelitis.

Figs. 914 915 Same as Figs. 910 and 911 after 24 weeks, or 12 weeks after the removal of the nail, and 3 weeks after removal of the wire suture. Fracture healed in good position with slight callus. Marked decalcification especially at the epiphyseal line of the distal end of the tibia. If only a wire suture and no medullary nail had been used, the fracture would have united sooner

Open Medullary Nailing of Old Fractures of the Lower Leg

Any adult with a leg fracture healed with a shortening of more than 2 cm with angulation of more than 15 or with a rotational deformity limps and subsequently develops disturbances in the knee and ankle joints These malpositions should therefore be corrected if the general condition the local conditions and the external circumstances permit

With angulatory deformities the patient may be free from discomfort for 10–20 years but then arthrotic changes may develop (see Böhler Der Chirurg No 4 1942) For this reason I have always straightened such fractures within the first few months while they were still soft by manipulation over a wooden wedge (Figs



Fig 916 Fig 917 Fig. 918 Fig 919 Fig. 920 Fig 921

November 2, 1943 January 1 1944 April 17 1944

Figs. 916, 917 *Compound* comminuted fracture of the left leg below the middle in a 29 year-old baggageman injured when a pile of doors struck his lower leg. After one hour thorough wound excision and debridement of all soiled bones with rongeur Application of 2 wire sutures. Unpadded plaster cast which was split immediately and fenestrated. Wounds healed without complications. Walking cast 3 weeks later

Figs. 918 919 Same as Figs 916 and 917 after 9 weeks. Good position Beginning callus formation Fracture still slightly springy New walking cast No appreciable decalcification of the epiphyseal ends of the bone

Figs. 920 921 Same as Figs. 916 and 917 after 5½ months. Bony union of the fracture with varus and recurvation of 5° each. Wounds closed. No swelling. Knee 180–70° against 180–40° on the right. All other joints actively free Starts light work. If a medullary nail had been used in this fracture it would probably not have healed so rapidly

868 E II/2488) or with the osteoclast of Phelps-Gocht (Figs 934 E, II/2746) or that of Schultze (Figs 933 E, II/2745) and continued the treatment with a plaster cast rarely with continuous traction

In these cases a firmer immobilization can be obtained with Küntscher s medullary nailing Selected cases operated upon with the proper technique need no supplementary plaster cast The muscles and joints damaged by the preceding prolonged immobilization can be exercised actively after healing of the wound, i e , usually after 2–3 weeks The great dangers of open nailing must be kept in mind, however before proceeding with this operation

This procedure is never urgent hence it should not be carried out unless the



Fig 922 Fig 923 Fig. 924 Fig 925

April 28 1942 May 11 1942

Figs. 922, 923 A 4-months-old spiral fracture of the left leg between middle and distal third and comminuted fracture of the fibula at the middle. Rifle shot injury in a 41 year old antique dealer Wound aseptic. *Elsasser* wire traction for 14 days with 10 Kg., then plaster cast. Tibia 2 cm shorter no trace of callus formation, bony union of fibula.

Figs. 924 925. Same as Figs. 922 and 923 after 13 days. Under general anesthesia, the fibula was broken over a wedge and wire traction applied to the calcaneus, at first with 5 Kg., later with 13 Kg. Shortening of the tibia corrected. A 2 cm. gap can be seen between the fragments of the fibula.

general condition is satisfactory the skin is normal and the shortening is less than 2 cm If the skin shows any type of pathology one must wait until it has returned to normal for at least 2 months. Extensive scars adhering to the bone are a contra-indication

If an attempt is made to correct a shortening of more than 2 cm during the operation, much force and much time will be required. Tissues are torn which will impair function later Nerve and circulatory disturbances from sudden correction of shortening are less common on the lower leg than on the thigh because the shortening is never so great The prolongation of the procedure may cause interference with asepsis and infection in the torn tissues is apt to occur Therefore any shortening should be corrected by continuous traction before medullary nailing

The history must be laid out in the same way as in fractures of the thigh (see pages 217 218)

Indications for operation on old fractures of the lower leg

1 Shortening of more than 2 cm

2 Angulation of more than 15°

3 Rotation of more than 15°



Figs. 926 927 Same as Figs. 922 and 923 three weeks after exposure of the fracture and medullary nailing. The fragments are in accurate apposition. The nail is sufficiently long and thick. It approaches the ankle joint to within 8 mm. along the anterior wall. Got up after 6 weeks with an Unna boot.

Figs. 928 929 Same as Figs. 922–925 after 8 months. Bony union in good position. The gap in the fibula bridged by bone.

Figs. 930 931 Same as Figs. 922–925 after removal of the medullary nail 10 months after nailing and 14 months after injury Bony consolidation Still some decalcification Ankle joint one-half limited. All other joints actively free. If instead of a nail, 2 wire loops had been applied, as in Figs. 904 and 905 and a walking cast 2 weeks later he would have been able to walk in the third week and with this simpler and less dangerous method the fracture would also have become firm in 8–10 weeks.

4 Delayed callus formation, especially that due to excessive traction

Contra indications to open medullary nailing of old fractures of the lower leg

1 Poor general condition All internal organs, especially those of circulation, must be in a healthy condition

2 Age of over 40 years. Only exceptionally should nailing be performed in older people

3 Local inflammatory processes on the bone Sinuses must have been closed for at least one year Under the protection of penicillin it might be possible to operate sooner

4 Marked osteoporosis with circulatory disturbances In dystrophic limbs the danger of infection following operation is greater

5 Skin pathology (inflammations, extensive adherent scars)

6 Shortening of more than 2 cm must be corrected beforehand by continuous traction

7 Extensive ossification of the medullary canal

8 Marked impairment of the muscles and joints

Correction of the shortening by continuous traction after closed refracture of the bone Within the first 3–6 months it is usually possible to break the still soft bone over a wooden wedge (Figs. 868 E II/2488) with the osteoclast of Phelps-Gocht (Figs. 934 E II/2746) or that of Schultze (Figs 933 E II/2745) and to straighten it (Figs 922 923) A wire or pin traction with 5 Kg is then applied to the heel. After 2 days the position is checked with X ray pictures and if the shortening persists, the weights are increased until it disappears In the case of Figs 924 and 925 a weight of 13 Kg was needed for the correction of the shortening within 13 days The fragments of the fibula then showed a separation by 2 cm.

Open nailing in old fractures of the lower leg Only after any existing shortening has been corrected or if none had existed may the nailing be performed.

Determination of the length and width of the medullary canal On X ray pictures of sufficient size the narrowest area of the canal is measured (Figs 12–20) The nail must be 1–2 mm thinner than this measurement The length is determined on the well leg with the knee flexed at a right angle as described on page 251

The instruments and apparatus described on pages 22–26 and illustrated in Figs 67–91 must be prepared A reduction apparatus is not needed nor a second X ray machine

Protection against heat loss Since the operation may be protracted the well leg the trunk and the arms must be well covered.

Positioning The patient lies on the back

Anesthesia General or spinal anesthesia may be used. No preliminary medication which might dangerously lower the blood pressure should be given when spinal anesthesia is contemplated

Bloodless field To work quickly and without loss of blood the leg is expressed with a rubber bandage and a tourniquet is applied on the thigh

Exposure of the bone The fibula is exposed first and divided obliquely with a chisel Periosteum and fascia are then sutured If this is omitted, the muscles will be so swollen by the end of the operation that the fascia can hardly be closed The tibia is then exposed by a straight incision over its medial aspect. We no longer use curved incisions since these were frequently followed by marginal necroses. The periosteum must be protected as much as possible otherwise large medullary sequestra will form (Figs 511–513 515–526) should the healing of the wound be disturbed. The operation is simplest if no callus has formed as yet, as in Figs 922–925 It is then sufficient to freshen the fragments with a sharp chisel whereupon they can be approximated accurately and without difficulty

Guide groove If the fracture ends have been absorbed, a guide groove 5–6 cm long and 1–2 mm deep and wide is chiseled into both fragments before they are severed. This will later serve as an indicator for avoiding or correcting rotatory displacement

Severance of the fragments By bending the leg the fibrous union can be disrupted In transverse fractures the fragments are then freshened with oblique or Z shaped saw-cuts because with transverse freshening callus formation is always greatly delayed.

Pus pockets If a cavity filled with granulation tissue or pus is met during the exposure of the fragments, the operation must be terminated This is a contra indication even for later medullary nailing

Exposure of the medullary canal If the medullary cavities are not patent after freshening of the fragments, they are opened with the awl or a hollow chisel

Removal of tourniquet The tourniquet is then removed Spurting blood vessels can readily be clamped, even on the posterior surface of the bone Ligation is usually not necessary

The subsequent steps are the same as in the closed medullary nailing of leg fractures (see pages 256–262), viz

Transverse skin incision at the nailing site,
Application of the spring clip
Piercing with the awl
Introduction of the guide pin for measuring
X ray pictures,
Rapid development,
Insertion of nail
More X ray pictures
Straightening of leg
Impaction of fragments,
Post-operative positioning of the leg
Removal of drains and open wound treatment,
Exercises,
Removal of sutures
Osteotomy of the fibula and
Follow-up

Open Medullary Nailing of Mal united Fractures of the Lower Leg

In firmly consolidated fractures I have always practiced open osteotomy and in fractures of the shaft I have used wire suture and plaster cast (Figs. II/2558–2575) Para articular fractures were sometimes given merely a plaster cast (Figs II/2576–2581)

For shaft fractures Küntscher's medullary nailing sometimes constitutes an advance because in selected cases and with proper technique no supplementary plaster cast is needed and all joints may be actively exercised after wound healing i.e after 2–3 weeks

The same indications contra-indications and requirements prevail as for the nailing of old fractures (see pages 280–283)

Determination of the type and location of osteotomy Paper patterns are made by tracing the X ray pictures on transparent paper and cutting them out (Figs II/2574 2578) If a lengthening is desired a steeply oblique cut is made through the pattern of the bone starting from the convex side leaving the concave border intact (Fig II/2574) If the pattern of the distal fragment is now moved until the bone is straight the overlapping segment indicates exactly to the millimeter the size of



Fig 932 Fig. 933 Fig. 934 Fig. 935

May 22, 1942 June 10 1942

Figs. 932 933 A 1½ year-old mal united fracture of the left tibia with antecurvation of 10–12° and varus of 15° in a 47 year-old woman farmer who was struck by a log The wound had been excised and sutured elsewhere then plaster cast for 4 months. At first the leg was straight but bowed after a few weeks because the cast was removed before the fracture was firm

Figs. 934 935 Same as Figs. 932 and 933 after osteotomy of the tibia and fibula and during the nailing. The curved iron (Fig. 76) for the protection of the skin can be seen plainly It slipped upward while the picture was being taken The fragments are not yet impacted

the bone wedge to be removed If the angular deformity of the tibia (varus or or valgus) is in the frontal plane, the fibula must be cut obliquely in the frontal plane and not transversely as in Fig II/2578 If angulation in the sagittal plane (antecurvation or recurvation) is to be corrected, the fibula must be severed obliquely in the sagittal plane If the angulation involves both planes, a resection of 1–2 cm is made from the fibula and a wedge from the tibia must be removed accordingly in a plane between the two main directions

The following measures are carried out in the same way as in old fractures (see page 284)

Determination of the length and width of the medullary canal,
Preparation of instruments and apparatus
Protection against heat loss
Positioning
Anesthesia
Bloodless field,
Exposure of bone
Osteotomy of the fibula



Fig 936 Fig 937 Fig 938 Fig 939

August 4, 1942 January 29 1943

Figs. 936 937 Same as Figs. 932–935 after 2 months. The fracture line begins to obliterate.

Figs. 938 939 Same as Figs. 934 and 935, after removal of the nail 7 months after the operation. Good position Bony consolidation. All joints actively free, muscles strong Walks well.

Procedure in case of pus pockets,

Making of a guide groove

Severance of the tibia The bone is exposed by a straight incision over its medial surface With curved incisions we have frequently met marginal necroses The periosteum must be protected as much as possible, otherwise, large medullary sequestra will form if infection intervenes (Figs 511–513, 515–526) The bone is cut with an osteotome or an electric saw obliquely or Z-shaped, but not transversely If a wedge is removed with a chisel, the bone must not be cut completely through on one side of the wedge, since it will then not offer enough resistance for the second cut, one should proceed along both sides of the wedge simultaneously For better stability a sandbag is placed under the leg If a rotatory deformity is to be corrected with an oblique osteotomy a second wedge must be removed, with an anterior base in the event of outward rotation and with a posterior base in the event of inward rotation After removal of the wedge, the fragments are coapted to see if they fit accurately If they do not they are reshaped

The subsequent steps are the same as in the medullary nailing of closed fractures of the lower leg (see pages 256–262)

Exposure of the medullary cavities,

Removal of tourniquet

Transverse skin incision

Application of a spring clip,
Insertion of the awl
Introduction of the guide pin for measuring,
X ray pictures,
Rapid development,
Driving of the nail,
Further X ray pictures,
Straightening of the leg,
Post-operative positioning,
Removal of drains and open wound treatment,
Exercises,
Removal of sutures,
Resection of fibula,
Followup

The prospects of bony union in correct alignment are good with proper technique (Figs 932–939) With transverse freshening, the healing is rarely as rapid as in Figs 932–939

If both legs show mal union the operation should not be performed on both of them at one time I have been informed of a case in which the operation was very much prolonged because of various difficulties The patient died a few hours later from the trauma of the anesthesia and the operation

As a rule medullary nailing should not be used in the correction of mal united leg fractures since with an oblique or a step-down osteotomy a wire suture alone is the much simpler and less dangerous procedure

Rejection of Open Medullary Nailing of Pseudarthrosis of the Tibia

Pseudarthrosis of the tibia does not cause as serious a disturbance as that of the femur since the fibula provides a certain amount of support Pseudarthrosis of both bones is very rare Since the use of the leg is considerably impaired, however we aim to correct this condition if the general and local conditions of the patient permit

Causes of pseudarthrosis Removal of fragments in compound fractures was formerly the most common cause

It also follows premature interruption of the immobilization for the purpose of applying massage and exercises.

The most frequent cause at the present time in closed as well as in compound fractures is excessive skeletal traction (Figs 515 516 940–971) With the leg on a Braun frame the weight for traction through the os calcis (Figs. 841 E II/2374) should as a rule be no more than 2–3 Kg with a simultaneous plaster cast (Figs 869 E, II/2509) 4–5 Kg If heavier weights are used the fragments separate and callus formation on the tibia stops instantly The fibula, being surrounded by muscles, usually unites thereby acting as a strut even after the weight has been removed. For this reason pseudarthrosis is much more common on the tibia than on the femur Occasionally a traction of 10 Kg applied for 2 weeks is sufficient

to produce pseudarthrosis If this undue traction acts longer, serious circulatory disturbances of the foot and lower leg ensue The bones become decalcified (Figs 352–355), the muscles waste, the joints stiffen, the skin becomes bluish and later scaly, and the foot becomes narrower and shorter (Figs 356, 357) The great number of cases of pseudarthrosis which have lately become evident would be considerably less if traumatic surgery were organized in the manner described on pages II/1525–1530 and if independent institutions for the teaching and treatment of traumatic



Fig. 940 Fig. 941 Fig. 942 Fig. 943

May 2 1943 August 12 1943

Figs. 940 941 A 5-months-old pseudarthrosis of the right tibia in an 18-year-old student from a fall while skiing Treated *elsewhere* with *wire traction of 6 Kg* for 8 weeks, then plaster cast for 3 months.

Figs. 942, 943 Same as Figs. 940 and 941 after 3 months, after oblique osteotomy of the fibula, freshening of the tibial fragments, insertion of nail and encircling with 2 wire sutures. The freshened ends are in accurate apposition. Before the wiring the fracture was entirely loose, even after nailing. Circular plaster cuff from ankle to hip Got up on the 17th day and left the hospital on the 23rd day Bony union of the tibial fracture If only 2 wire loops and a circular plaster cast had been used, it would have healed just as quickly through a much simpler and less dangerous procedure.

surgery were created Such unduly prolonged periods of treatment as described in Figs 952–959 and 960–971 would then not recur

Osteotomy or resection of the fibula To obtain bony union in a comparatively fresh pseudarthrosis of the tibia it is sufficient to make an osteotomy or a small resection of the fibula and to apply an unpadded walking cast up to the middle of the thigh with good axial alignment of the tibia (Figs II/2582–2585)

Bone drilling according to Beck Formerly we used Beck s drilling in contact pseudarthrosis quite frequently with simultaneous osteotomy of the tibia and obtained bony union (Figs 170–177, 860–867 E, I/257–264 II/2590–2597) In suitable cases we have again reverted to this method

Application of a spring clip
Insertion of the awl,
Introduction of the guide pin for measuring,
X ray pictures,
Rapid development
Driving of the nail,
Further X ray pictures,
Straightening of the leg,
Post-operative positioning,
Removal of drains and open wound treatment,
Exercises,
Removal of sutures,
Resection of fibula,
Followup

The prospects of bony union in correct alignment are good with proper technique (Figs 932–939) With transverse freshening the healing is rarely as rapid as in Figs 932–939

If both legs show mal union the operation should not be performed on both of them at one time I have been informed of a case in which the operation was very much prolonged because of various difficulties. The patient died a few hours later from the trauma of the anesthesia and the operation

As a rule medullary nailing should not be used in the correction of mal united leg fractures since with an oblique or a step-down osteotomy, a wire suture alone is the much simpler and less dangerous procedure

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The most frequent cause at the present time in closed as well as in compound fractures is excessive skeletal traction (Figs 515 516 940–971) With the leg on a Braun frame the weight for traction through the os calcis (Figs 841 E II/2374) should as a rule be no more than 2–3 Kg with a simultaneous plaster cast (Figs 869 E II/2509) 4–5 Kg If heavier weights are used the fragments separate and callus formation on the tibia stops instantly The fibula being surrounded by muscles, usually unites thereby acting as a strut even after the weight has been removed For this reason pseudarthrosis is much more common on the tibia than on the femur Occasionally a traction of 10 Kg applied for 2 weeks is sufficient



Fig 948 Fig. 949 Fig 950 Fig 951

September 9 1942 March 4 1943

Figs. 948, 949 Same as Figs. 944–947, after 5 months. Bony union in good position.

Figs. 950, 951 Same as Figs. 944–947 after extraction of the nail 11 months after the operation and 16 months after the accident. Bony consolidation of the fracture. Still some decalcification Motion of ankle and subastragalar joints one half limited other joints actively free Still discomfort on walking. If in this case only the 4 wire loops had been used healing would have been obtained just as quickly by a simpler and less dangerous measure.

"The operation is performed in the same manner as in old leg fractures (see pages 284 285) It is of paramount importance that the fragments be freshened transversely or obliquely by saw or chisel within the healthy zone and well coapted Medullary nailing has failed in many cases because freshening was omitted The fragments must be accurately matched and provided with supplementary longitudinal or transverse wire sutures (Figs. 942, 943 946–951) The short proximal fragment of Figs. 940 and 941 was still quite loose after the nail had been driven in. Only after the application of two circumferential wire loops was sufficient stability attained. The wires alone would not have provided adequate fixation In the case of Figs. 944–951 four circumferential wires had to be used because the loosely attached butterfly fragment broke loose during the operation.

"In Figs 952–959 callus formation was very slow after the operation because both fragments were extremely sclerosed for a distance of 4–5 cm and because the fibula was at first merely osteotomized obliquely and not resected The medullary canal could be opened only with a round burr

"Medullary nailing is simpler than bone grafting and apparently equally successful.

Complications Figures 976–983 show that medullary nailing causes more damage than good if the contra indications given on page 290 are ignored.

"*Case* A 22 year-old woman had been stricken at the age of 4 with acute osteomyelitis which was followed by pseudarthrosis of the tibia. She used an orthopaedic apparatus until the age of 14 then no appliance until she was 19 During this time the leg bowed. In 1940 she was



Fig 944 Fig 945 Fig. 946 Fig 947

April 15 1942 April 22, 1942

Figs. 944 945 A 5-months-old pseudarthrosis of the leg with marked decalcification, in a 40-year-old blacksmith from slipping on the street. Treated *elsewhere* with *wire traction of 8–12 Kg* for 6 weeks. Then plaster cast for 3 months. Fibula firmly united, tibia shows no trace of callus formation. No appreciable shortening.

Figs. 946 947 Same as Figs. 944 and 945 after exposure of the fragments and medullary nailing. During the operation the long butterfly fragment became loose. It was fastened with 4 wire loops. The nail is sufficiently thick and long and reaches to within 5 mm of the ankle joint along the anterior wall.

Oblique freshening and wire suture or bone grafting is preferable for many cases (Figs. II/2586–2589 and II/2598–2605)

Medullary nailing Recently we have treated suitable cases of pseudarthrosis with medullary nailing In the first edition I wrote concerning this

'Essentially the same contra indications prevail as for old leg fractures

1 Poor general condition. All internal organs especially those of circulation, must be in good condition.
2 Age over 40 years. Operation in older people should be an exception.
3 Local inflammatory conditions of the bone. Sinuses must have been closed for at least one year
4 Marked decalcification of the bones with simultaneous other circulatory disturbances. Dystrophic limbs are particularly prone to post-operative infection
5 Skin pathology (inflammation, adherent extensive scars)
6 Shortening of more than 2 cm. This must be corrected by continuous traction before operation.
7 Extensive ossification of the medullary canal

Marked impairment of the muscles and joints is no contra indication.



Fig. 956 Fig. 957 Fig 958 Fig 959

February 23 1943 October 7 1943

Figs. 956, 957 Same as Figs. 952 and 953 after 10 months. The fracture line of the tibia is not yet closed. Fibula shows bony union.

Figs. 958, 959 Same as Figs 956 and 957 17 months after the first operation and 5 months after resection of a piece of the fibula and insertion of a longer medullary nail. The fracture is partly bridged. If in this case a massive tibial graft 10–12 cm. in length had been transplanted after osteotomy of the fibula and after freshening of the fragments, the pseudarthrosis would probably have united in 3–4 months without nailing, as in Figs. II/2598–2605

tibia by the sequestration another resection of the fibula was taken into consideration on June 10 but was not performed On Aug 10 the nail was extracted, whereupon the wound quickly became smaller The leg was shorter by 6 cm. On Oct 15 the fibula was firmly united and the wound was closed. There was still a pseudarthrosis of the tibia (Figs. 982 983) A new walking cast was applied which was renewed thereafter every 4 months On May 15 1944 i.e. 1½ years after the operation, both bones were finally united firmly but the leg was 6 cm. shorter

In this case the essential features of the pathology were never rightly understood and improper measures were taken repeatedly No operation should be performed in the presence of scars adherent to the bone because these usually become necrotic, expose the operation on the bone and lead to suppuration. In this case not only the skin but also the bone was seriously affected The distal half of the tibia was markedly stunted in growth was thin and decalcified The fracture ends, however were sclerosed and poorly nourished. Such eburnized bone like decalcified bone is particularly susceptible to infection and prone to become sequestrated. The fibula which had carried the weight of the body for 17 years was thicker than the tibia in some areas The osteotomy of the fibula with removal of the graft performed in 1940 constituted a serious injury to the weight bearing bone and caused a shortening of the leg Beck s bone drilling is usually unsuccessful with this type of bone stumps The resection of the fibula in 1942 entailed another serious injury to the leg The sloughing of the adherent scars following medullary nailing caused sequestration which

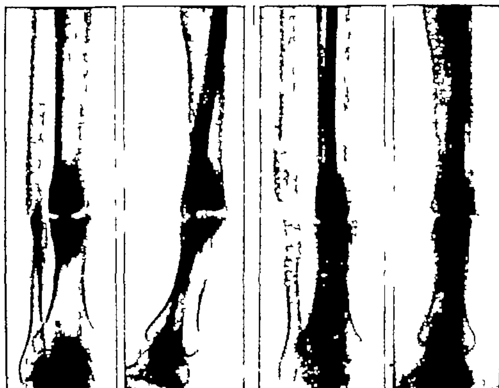


Fig. 952 Fig. 953 Fig. 954 Fig. 955

May 11 1942 July 23 1942

Figs. 952, 953 A 4-year-old pseudarthrosis of the right tibia with marked sclerosis of both fracture stumps for a distance of 4–5 cm. Recurvation of 15 In a 24-year-old officer injured in a motorcycle accident. Treated *elsewhere* with *wire traction of 10 Kg* for 9 weeks. Then walking cast for 4 months. Later removable cast for 2 months and daily striking of fracture site with a wooden mallet. Then Beck's drilling of the fragment without severing the fibula. Four months later osteotomy of the fibula and another walking cast. After 2 years, transplantation of a short thin tibial graft, then walking cast for 5 months. After 3 years, orthopaedic brace.

Figs. 954, 955 Same as Figs. 952 and 953 two months after osteotomy of the fibula, transverse freshening of both tibial fragments, removal of a wedge with 8 mm posterior base from the distal fragment, opening of both medullary cavities with electric burr and insertion of the nail. The fragments are in good apposition without angulation. The nail is too short.

operated upon elsewhere The fibula was osteotomized and a small graft from it was implanted into the tibia. On the 5th day fever and suppuration developed and the graft separated after a few weeks. Ten months later the wound was closed. One year later Beck's drilling was done. On Oct. 14 1942 the following findings were recorded in the case The lower leg shows a varus bowing On its anterior surface there is a scar 16 cm long and 4 cm. wide the middle of which is adherent to the bone in the region of the pseudarthrosis for an area of 5 x 4 cm. A readily movable operative scar 9 cm. long is located over the fibula. The circulation is good. Shortening 3 cm. On Oct. 24 1942 the fibula was severed obliquely and a 1½ cm. piece was resected (Fig 978) The tibia was then exposed subperiosteally through an incision outside the adherent scars. Both fragments were freshened and united with a medullary nail (Figs 978–979) Both operative wounds healed without disturbances On Oct 31 a dry necrosis of 2 x 1½ cm developed within the adherent area of the old scars Four weeks later the bone lay bare in this region for an area of 5 x 6 mm. Suppuration was marked at times, then again slight without fever From Dec. 8 1942 to Jan. 20 1943 several small sequestra separated almost every week. On Jan. 27 1943 several larger sequestra were removed under general anesthesia Since a defect had formed in the

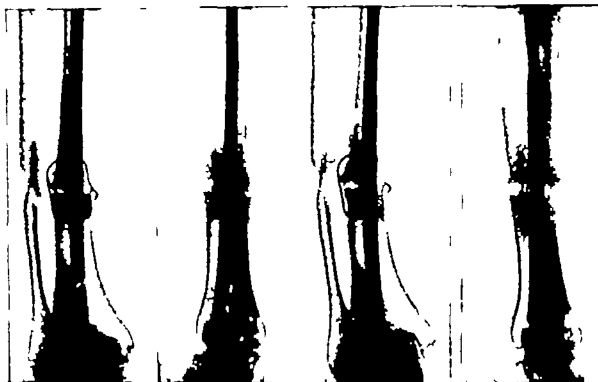


Fig. 964 Fig. 965 Fig. 966 Fig. 967

September 8 1943 November 11 1943



Fig. 968 Fig. 969 Fig. 970 Fig. 971

November 14, 1943 January 5 1945



Fig. 960 Fig. 961 Fig. 962 Fig. 963

June 8 1943 June 9 1943

Figs. 960 961 A 16-months-old pseudarthrosis of the right tibia between the middle and lower third with 15° varus and 15° antecurvation in a 32 year-old teamster who was run over by a wagon. Treated *elsewhere* with calcaneal wire traction of 14 Kg for 15 weeks. Then walking cast and administration of many allegedly callus-forming medicines.

Figs. 962 963 Same as Figs. 960 and 961 after transverse freshening of both fragments, insertion of a *medullary nail of proper length and thickness and application of a longitudinal wire suture to hold the* fragments firmly together Oblique resection of the fibula. Excellent position of tibial fragments. Fracture line hardly visible Application of a plaster cast up to the middle of the thigh this was split immediately After 10 days, application of an unpadded cast up to the middle of the thigh.

Figs. 964 965 Same as Figs. 962 and 963 after 3 months. The fracture line has become wider Slight callus formation laterally and posteriorly Bony union of the fibula. Application of an unpadded plaster cast up to the knee only

Figs. 966, 967 Same as Figs. 964 and 965 after 2 months, and 5 months after the operation. Fracture line widened. Callus increased posteriorly In spite of the medullary nail the supplementary wiring and plaster cast, a varus angulation of 15° has recurred.

Figs. 968, 969 Same as Figs. 966 and 967 after removal of the nail and wire suture and liberal resection of the fibula and straightening of the leg. The fracture line gaps anteriorly and medially An unpadded walking cast was applied 10 days later up to the middle of the thigh.

Figs. 970 971 Same as Figs. 968 and 969 after 14 months, and 19 months after the first operation Bony union of fracture. The fibular defect has not filled in. This area is still tender to pressure. If in this case an osteotomy *of the fibula and Beck's drilling of the tibial fragments had been performed as in Figs. 170–177* 860–867 E, I/257–264 and II 2590–2597 or a bone grafting as in Figs. II 2598–2605 the pseudarthrosis would probably have consolidated in 3–4 months.

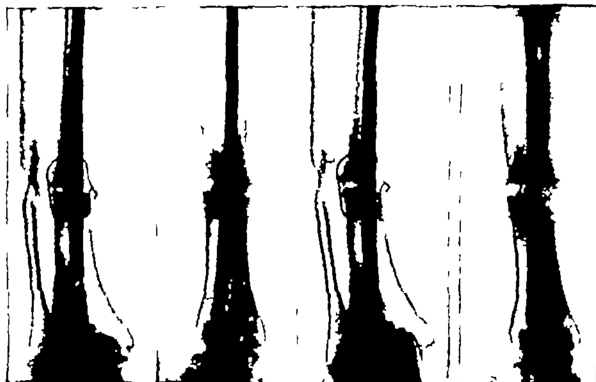


Fig. 964 Fig. 965

September 8, 1943

Fig. 966 Fig. 967

November 11 1943



Fig. 968 Fig. 969

November 14 1943

Fig. 970 Fig. 971

January 5 1945



Fig. 972 Fig. 973 Fig. 974 Fig. 975

August 25 1942 May 20, 1943

Figs. 972, 973 Defect pseudarthrosis of the tibia in a 47 year-old foreman who was injured in a motorcycle accident. Compound leg fracture with massive sequestration following Beck's drilling.

Figs. 974 975. Same as Figs. 972 and 973 nine months after osteotomy of the fibula and medullary nailing. The osteotomy permitted the tibial fragments to approximate by 2 cm. The gap however is still wide and no trace of callus has formed.

Figs. 976 977 Pseudarthrosis of the tibia with thickening of the fibula. Found in a 22 year-old woman who had an acute osteomyelitis at the age of 4. The tibia is markedly underdeveloped from stunted growth. Its distal half which did not carry weight is very thin and decalcified the fracture stumps, however are sclerosed and have poor circulation. The pseudarthrosis shows the shape of a ball and socket joint. The proximal tibial fragment is subluxated distally in relation to the fibula which is much longer and carries the weight, the distal tibial fragment is subluxated proximally giving the external malleolus an abnormally long appearance. The fibula is much thickened and below the middle it is much thicker than the tibia. It shows a healed fracture from osteotomy.

Figs. 978, 979 Same as Figs. 976 and 977 after resection of the fibula and freshening and medullary nailing of the tibia. The 2 drains which were inserted for 24 hours are plainly seen.

Figs. 980 981 Same as Figs. 978 and 979 after 4 months. The fragments of the fibula overlap. On the tibia, however a gap persists because of sequestration, although the fragments had approximated. Because of the shortening of the tibia, the nail plowed upwards.

Figs. 982, 983. Same as Figs. 976 and 977 after one year. The fibula united again but on the tibia there is a pseudarthrosis. The nail track is strikingly conspicuous. The lower leg is 3 cm shorter than before the second operation and 6 cm. shorter than before the first. In May 1944 both bones were healed with fairly good callus. In this case it would have been a better procedure to transplant the tibia upon the fibula, as in Figs. II/2606–2609



Fig 976



Fig. 977

October 14 1942



Fig 978



Fig 979

October 24 1942

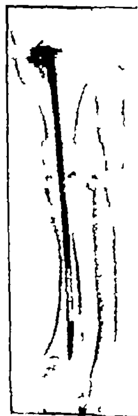


Fig 980



Fig 981

February 6 1943



Fig 982



Fig 983

October 15 1943

led to a shortening of the leg by an additional 3 cm The final result 1½ years after the operation was union of the bones but a shortening of 6 cm. The lower leg is 6 cm. shorter than before the first operation

Osteotomy or a *sparing resection of the fibula* frequently leads to healing in comparatively fresh cases of pseudarthrosis, but in old cases with sclerosed fracture stumps it is usually ineffective Resection of the fibula must be done only if shortening is negligible and it must not be repeated indiscriminately One must be very careful with extensive resection of the fibula because the defect is not always bridged (Figs. 968–971) If at the same time the tibia does not unite the patient is much worse off than before the operation and cannot bear weight without a brace. I have quite frequently seen this condition and its disabling effect following gunshot defects of the tibia because the fibula had been resected too extensively

For a case as shown in Figs. 976, 977 the only operation that should be considered at present is a transplantation of the thickened fibula into the tibia, as in Figs II/2606–2609 This transfers the body weight directly upon the fibula and the leg is not shortened Then no further displacement of the metaphyses of the short tibia in relation to the longer fibula can take place

Prohibition of medullary nailing in pseudarthrosis of the tibia A critical study of cases of pseudarthrosis of the tibia which were treated by us and by others with a medullary nail revealed unfortunately that nailing offers no advantages over other methods but frequently entails great disadvantages. We have introduced it and used it for the particular reason that we put credence in the original assertions in the literature that the medullary nail stimulates callus formation the very desideratum in pseudarthrosis since it is due to lack or exhaustion of callus production Now however it has become evident that the medullary nail does not stimulate callus formation but rather retards it This is especially true in transversely freshened fractures It is most conspicuous in Figs. 960–971 Had this case had merely an oblique osteotomy of the fibula an unpadded walking cast would perhaps have brought about bony union as in Figs. II/2582–2585 Had this been unsuccessful, Beck's drilling correctly performed as in Figs. 170–177 and 860–867 E I/257–264 and II/2590–2597 or oblique freshening of the fragments with wire suture, as in Figs II/2586–2589 should have been used

If in the cases of Figs 940–943 and 944–951 only wire sutures and no nails had been used after thorough freshening of the fracture stump union would have been obtained just as rapidly and in a simpler and less dangerous way We must always keep in mind that infections following open medullary nailing have much more serious consequences than those following other operative procedures, because the entire medullary canal is opened and may become involved in the inflammatory process

Since I have seen no worthwhile advantages from open medullary nailing of pseudarthrosis of the tibia but have noticed great disadvantages and dangers (delayed callus formation and infection) I have prohibited its use within my jurisdiction, since many surgeons are so anxious to perform this operation that they are

willing to assume responsibility for the risks involved, even after the dangers and disadvantages have been pointed out to them

Rejection of Open Medullary Nailing of Defect Pseudarthrosis of the Tibia

In the belief that the medullary nail exerts a callus-stimulating effect it has variously been tried for the cure of defect pseudarthrosis. All such attempts have failed In our experience such defects can be bridged only by fresh bone grafts, preferably from the well tibia, provided that the condition of the skin is good Usually, however extensive contracted scars are present, which can be repaired only with difficulty by skin flap grafts, therefore, bone grafting is possible only in a very few cases The best procedure is then to transplant the fibula into the tibia, since it has usually increased in thickness if a defect had existed in the tibia for some time, as shown in Figs II/2606–2609

Figures 972–975 show that no trace of callus had formed 9 months after medullary nailing In this case, too, bad scars led to skin necrosis, infection and the separation of numerous small medullary sequestra.

JOINT FRACTURES

Open Medullary Nailing of Pirogoff Stumps and Joint Resections

Recently it has been suggested that infected and resected joints be treated with a medullary nail My experience with cases of this type nailed elsewhere has induced me to sound an urgent warning against it

Case In a 48-year-old man the fore part of the left foot was run over and crushed by a locomotive. A Pirogoff amputation was done. For the fastening of the heel stump a double medullary nail was driven from the region of the tibial tuberosity through the entire tibia until it protruded through the distal saw cut whereupon, the heel stump was apposed and the nail driven further It entered the os calcis only at its margin thus providing insufficient stability On the third day the temperature rose to 39°C and the stump was swollen and red. Some sutures were removed On the 4th day the entire lower leg became swollen and painful. At the nailing site there was fluctuation and bloody secretion was evacuated upon pressure. Several incisions were made on the lower leg The pulse deteriorated and the patient died one hour later

Unfortunately no necropsy of the bone was made It was apparently a case of acute phlegmonous myelitis of the medullary cavity In this case the conditions were entirely different from a fracture because the entire medullary cavity was closed with the exception of the entrance and exit sites of the nail and therefore marked pressure developed inside the bone

For Pirogoff stumps it is preferable to drive 2 ordinary pins crosswise through the metaphysis of the tibia and the os calcis They provide good stability and do not open the medullary cavity It is still more simple to unite both bones with a wire loop

In *aseptic resections of the knee joint* we always use 2 pins driven crosswise through the metaphysis of the tibia and femur which provide a firm hold until the plaster cast is applied. In infected joints it is better to use transverse transfixion with wire through both the tibia and the femur, far removed from the inflamed area



Fig 984
February 26 1942



Fig 985
April 17 1942

Fig 984 Pseudarthrosis of the left clavicle, 8 months after injury The fracture was sutured *elsewhere twice with a thin wire, after 4 weeks and after 10 weeks. Each time merely 14 days immobilization,* followed by vigorous massage and forcible passive movements. The wire broke after both operations.

Fig. 985 Same as Fig 984 after 7 weeks. The broken wire loop was removed. Both fragments were freshened transversely the central end of the clavicle drilled with the burr and a nail was inserted. Immobilization with shoulder spica for 6 weeks. After 7 weeks bony union of the fragments.

The suggestion to drive a long medullary nail from the trochanter through the length of the femur into the tibia *in infected knee joints* appears to me extremely dan gerous because this may lead to an inflammation in the medullary cavities of both bones

The use of a medullary nail following resection of the shoulder joint is illogical (Fig 987) because an arthrodesis can be achieved only through a firm contact be tween the 2 bones by a wire suture

FRACTURES OF THE METATARSAL BONES

Open Medullary Nailing of Metatarsal Fractures

In the first edition I wrote In transverse fractures of the middle of the shaft with marked lateral displacement and shortening as in Figs 1030 E, II/3000, open medullary nailing appears indicated if the skin conditions are satisfactory the same holds true for markedly displaced transverse fractures of the metacarpal bones (Figs. 1252–1255) In view of my experiences with open medullary nailing of fractures of the tibia, I am inclined to advise against this operation in fractures of the metatarsal and metacarpal bones.

FRACTURES OF THE CLAVICLE

Closed medullary nailing can hardly be considered for fresh closed fractures of the clavicle, because it is impossible to use fluoroscopy in 2 planes during the operation this might lead to injuries to the nerves and blood vessels by the medullary nail.

Open medullary nailing of old clavicular fractures is to be preferred to simple wiring because it can prevent angulation as in Fig I/547 and lateral displacement. A wire suture must be added to prevent a separation of the fragments As a rule this operation should be avoided because of the danger of infection

Open Medullary Nailing of Pseudarthrosis of the Clavicle

Open medullary nailing of pseudarthrosis of the clavicle is a much simpler pro cedure than the transplantation of a bone graft from the tibia. The clavicle is ex



Fig 986
August 19 1942



Fig 987
October 15 1942

Fig 986 Condition 6 months after resection of the shoulder joint There is a gap of 5 cm. between the glenoid cavity and the humerus stump A 3 cm. sequestrum in the humerus.

Fig 987 Same as Fig 986 6 weeks after removal of sequestrum and insertion of nail bridging the 5 cm. gap performed elsewhere Never will an ankylosis of the shoulder joint be obtained in this manner

posed under local anesthesia and the fragments are freshened with saw chisel or rongeur, obliquely or Z-shaped, until the medullary cavities are exposed With transverse freshening callus formation is always greatly delayed The medullary cavity is then entered either at the sternal (Fig 985) or at the acromial end (Figs 63-66) by means of a round burr the awl or a rongeur, and a nail of proper length and thickness is driven in As soon as it appears at the fracture it is guided into the other fragment and driven further Both fragments are then drilled and united with a wire suture, otherwise they might separate A Desault bandage is applied for 8 days. Exercises preferably on the horizontal and vertical pulley (see pages 1/21 and 22) can then be started carefully If no supplementary wire suture is applied a shoulder arm spica must be used for at least 6 weeks to prevent separation of the fragments and a recurrence of the pseudarthrosis.

I have now reverted to bone grafting because callus formation was very slow in most nailed pseudarthroses of the clavicle

DISLOCATIONS OF THE CLAVICLE

Open Medullary Nailing in Clavicular Dislocations

One surgeon tried open medullary nailing in 2 acromio-clavicular dislocations He exposed the joint, drilled the acromion and inserted the medullary nail through it and through the joint into the clavicle (Fig 989) A Desault bandage was used for 3 weeks In both cases the medullary nail shifted a few days after the arm was again used. In one case it moved centrally leaving the acromion so that the bones separated again (Fig 990) In the other case the nail migrated laterally leaving the clavicle After removal of the nail the position of the bones was in both cases the same as before the operation For a long time the motion of the shoulder however was much worse than before

Earlier many attempts had been made to correct acromio-clavicular dislocations by



Fig 988

February 2 1943

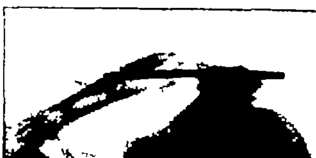


Fig 989

February 2 1943

Fig. 988. A 7 months-old acromio-clavicular dislocation in a 40-year-old man who fell from a horse.

Fig. 989 Same as Fig 988, after medullary nailing performed *elsewhere*. The bones are held in the proper position A Desault bandage was applied after operation.

the insertion of steel or bone pegs. These always broke because the weight of the entire arm hung on them The medullary nail is so strong that as a rule it does not break Since the stresses act at a right angle to its long axis, it cannot provide a hold and therefore motion causes it to migrate

The only rational operative procedure consists in exposing the coracoid process and reuniting it firmly with the clavicle by strong silk sutures thus replacing the torn coraco-clavicular ligaments (Figs 313–315 E, I/553–555 and I/559–561) Another strong silk suture is placed through the acromion and the clavicle. If wire is used instead of silk the wire will be found broken after a few weeks. The ends of the wire then frequently cause discomfort.

GUNSHOT INJURIES TO THE SHOULDER JOINT

Open Medullary Nailing following Resection of the Shoulder Joint

Trusting to the callus-forming effect of the medullary nail one surgeon united the humerus to the glenoid cavity with a medullary nail without bringing these two bones into full contact (Fig 987) whereupon he applied a shoulder spica The procedure was unsuccessful in both cases and the nail had to be removed. In the meantime I have seen several more similar failures.

Bony union can be obtained in shoulder resection only by waiting for at least 6 months after the sinuses have closed. Both bones must be freshened and held together with wire One wire fastens the humerus to the acromion the other to the glenoid cavity This is followed by a shoulder spica with the arm in abduction and anteversion of 45° each

FRACTURES OF THE HUMERUS

Closed Medullary Nailing of Humerus Fractures

General requirements with regard to the patient Medullary nailing of the humerus must be performed only if the patient is in good general condition. Heart lungs,



Fig 990

March 8 1943



Fig 991

March 16 1943

Fig. 990 Same as Fig 989 after 5 weeks. Three weeks after the operation the Desault bandage was removed and exercises were started, which caused the nail to travel medially It has left the acromion. This operation can never be successful.

Fig. 991 Same as Figs 989 and 990 after removal of the nail. The condition is again the same as before the operation shown in Fig 988

kidneys reflexes motion of all joints and sensation must be carefully tested The skin must be healthy and must not show any injury or inflammation, even outside the fracture. No infection must be present in other parts of the body (e.g , tonsillitis)

Local requirements with regard to the patient Transverse fractures in the middle third are most suitable (Figs 1010–1023, 1054–1063), but also transverse fractures between the middle and distal third (Figs 1024–1031) and spiral fractures in the middle and upper third (Figs. 1001–1005) may be nailed

Contra indications with regard to the patient If the general condition is poor (weak, rapid pulse pale appearance cold sweat) medullary nailing must not be performed under any circumstances because it is not an emergency operation **If the patient is in a state of severe shock, as is frequently the case in multiple injuries, nailing must positively not be attempted because the outcome may be fatal** I am repeating this sentence in every chapter because some beginners forget this again and again In the presence of a patient s poor general condition, only a plaster cast or splint should be applied exceptionally, a wire traction with one, or at the most two, Kg of weight attached

Contra indications with regard to the soft tissues In *inflammatory conditions of the respiratory digestive or genito urinary tract* closed medullary nailing must not be performed because it may lead to a spread of the infection into the bone marrow Particular attention should be paid to tonsillitis.

Inflammatory conditions of the skin especially *furunculosis*, entail the danger of metastatic infection, therefore medullary nailing must not be performed

Burns especially on the injured limb are also a contra indication

In the presence of *wounds on other parts of the body* medullary nailing should be deferred until they have healed completely i e , at least 14 days after injury otherwise late inflammation and metastatic infection may ensue (see page 151)

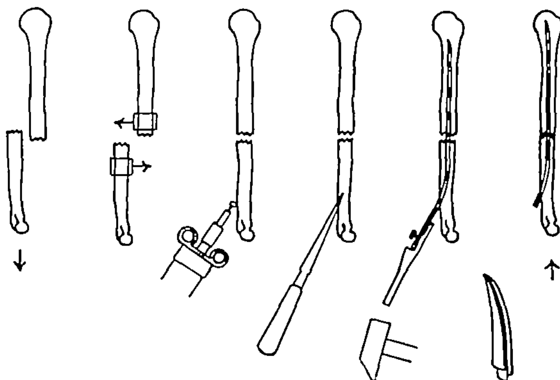


Fig 991 a–f

Fig 991 a. Transverse fracture of the humerus with marked shortening and lateral displacement.

Fig 991 b The shortening is corrected by lengthening, and traction straps are applied for the correction of the lateral displacement, as in Fig 998.

Fig 991 c. After exposure of the bone through a 5 cm. incision a hole is drilled with a round burr

Fig 991 d. The hole is widened with a straight awl (Fig. 73)

Fig 991 e. The medullary nail held in Kuntscher's handle (Fig 77) is driven in.

Fig 991 f The fragments are impacted.

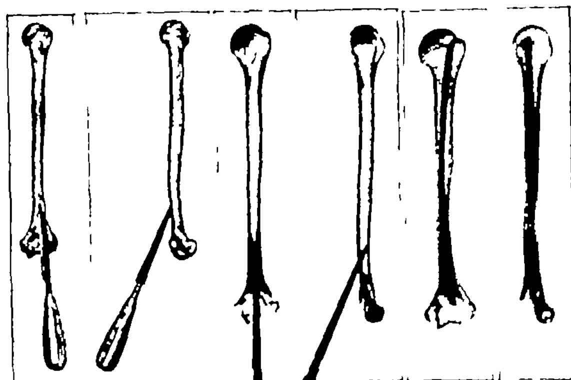
In the presence of *deep skin abrasions* over the fracture site nailing must be avoided because the sloughing of the contused skin may lead to exposure and infection of the fracture

Marked swelling is also a contra indication and one must wait until it has subsided. If *blebs* have formed which are a sign of marked circulatory disturbance, one must desist from medullary nailing

Contra indications with regard to the bone Splintered fractures spiral fractures with a long butterfly fragment and fractures in bone diseases which block the medullary canal e.g certain forms of Paget s disease are a contra indication The fractures must be at least 8–9 cm removed from the distal end and 5 cm from the proximal end of the bone

Instruments and apparatus listed on pages 22–26 and in Figs 67–107 must be in readiness. In addition, there are needed a stitched pad 9 x 16 cm and 1 cm thick, a short strap 6 x 32 cm (Fig I 755) a traction bow of 10 cm spread (Fig I/755) and a small self retaining wound retractor

Local anesthesia and X-ray pictures Good X ray pictures of adequate size taken in 2 planes are of prime importance To prevent pain when taking the lateral view,



Figs. 992 Fig. 993 Fig. 994 Fig. 995 Fig. 996 Fig. 997

Figs. 992, 993 The hole which had been drilled above the fossa olecrani with a round burr is widened with the awl

Figs. 994 995 Same as Figs 992 and 993 The awl penetrates the bone obliquely toward the anterior wall. Pictures by Güttner

Figs. 996 997 The nail strikes the anterior wall at the junction of the middle and distal third and is deflected toward the posterior wall below the middle. It then slides along the posterior wall toward the lateral side into the head of the humerus.

the fracture should be anesthetized locally (see page I 99) For a good over-all view in order not to overlook concomitant injuries (Fig 1001) and in order to be able to measure the width of the medullary canal accurately the pictures must be at least 40 cm long and should show both joints (Figs. 1010 1011) Shorter films (Figs 1024–1031) are unsatisfactory because the nailing site cannot be seen

Time of operation If the general condition is good, one may operate within the first few hours Fragments can most easily be replaced on the first day before an extensive hematoma or swelling develops If for some reason the operation cannot be performed within the first few hours, the nailing may be done in the next few days if the swelling is slight One must not operate if the swelling is marked so that the skin becomes shiny or if blebs have formed or in the presence of deep abrasions If wounds are present on the broken arm or on other parts of the body, unless the nailing can be done immediately after debridement of the wounds one must wait until they are well healed i.e 2–3 weeks otherwise they will break open and become inflamed and may cause metastatic infection of the fracture (see page 151)

Determination of the length and width of the medullary canal After X ray pictures have been obtained and the time of operation set, the length of both fragments is measured on the X ray pictures With a focus-film distance of 80 cm 1.5 cm must

be deducted from this measurement in order to obtain the actual length of the bone Since the nail is inserted 4–5 cm above the elbow joint and since it should reach to within 1–2 cm of the shoulder joint, another 5–7 cm must be deducted to compute the length of the nail required The majority of complications arise from the use of too short and too thin nails because these do not provide a sufficient hold The nail inserted from the elbow does not find anchorage until it has entered the cancellous area of the humeral neck and head It sits particularly tight when it has entered into the epiphyseal line The upper third of the shaft is very wide and contains no cancellous bone (Figs 23–31) The nail may therefore play if it is too short (Figs 470–475)

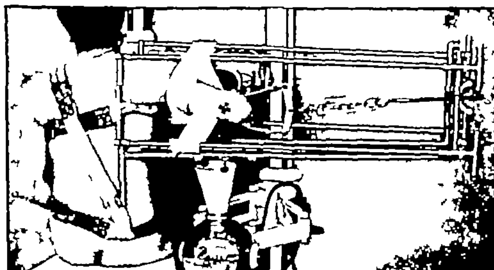


Fig 998

Fig 998. The humerus is secured in a screw traction apparatus under traction, the amount of which can be read on the spring scale After reduction the traction bow is connected directly to the hook of the traction screw by a cord passing the spring scale. The fragments are firmly secured after reduction so that they will not shift from the impact of the hammer blows. The nailing site is then marked with an "X" The patient must sit upright leaning against and fastened to the operating table for a convenient approach to the nailing site.

The width of the canal is measured on the X ray pictures. In adults the narrowest part of the distal third varies from 6–9 mm It widens progressively upwards towards the tuberosities where its width measures 20–25 mm If too thin a nail is used, the fragments may rotate and separate

Personnel The following personnel is needed an assistant for observation of the patient (appearance pulse) and sometimes for general anesthesia a fluoroscopist, an instrument nurse and an X ray technician

Anesthesia Plexus anesthesia is the best method If it does not work one may reduce under local anesthesia The nailing site must then be anesthetized separately If pain occurs during the driving of the nail a short general analgesia may be given

Protection against heat loss As with any other operation, the patient should be well covered to protect him against heat loss.

Securing the arm in the reduction apparatus The patient sits upright (Figs. 998–

1000) upon the operating table The back part of the operating table is raised so that he can lean firmly against it The thighs are strapped to the table After application of the screw traction apparatus another belt is placed around the chest to maintain the body in good position The screw traction apparatus with the 4 rotating rods (Figs 998 or 999) is fastened to the body with the 3 straps The arm is abducted laterally

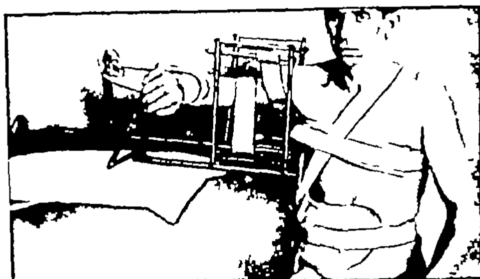


Fig 999

Fig. 999 Humerus fracture secured in Linsmayer's apparatus.

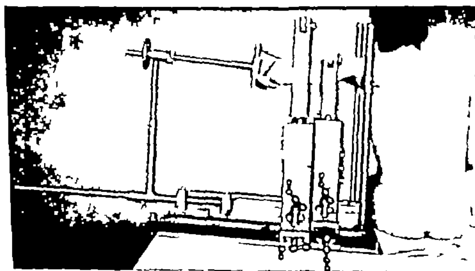


Fig 1000

Fig. 1000 Humerus fracture secured in Wittmoser's apparatus.

70–80°, with the elbow flexed at a right angle and so rotated that the shoulder is in mid-position between inward and outward rotation. The forearm is placed in mid position in fractures above the middle in fractures below the middle, it is placed in slight pronation (Fig 999) On the forearm immediately below the elbow, the stitched pad 9 x 16 cm and 1 cm thick is placed and the strap 6 x 32 cm , connected with a 10

cm. traction bow is placed over it (Fig I/755) The latter is then connected to the screw The hand is fastened to the bar of the forearm part of the splint (Figs. I/754-757)

If Wittmoser's reduction apparatus is used, the upper arm is placed through the 2 reduction rings and the forearm is fastened to the footplate (Fig 1000)

X ray apparatus One tube is placed opposite the medial side of the upper arm the other opposite the flexor surface (Fig 998)

Reduction By placing the arm in the position pictured in Figs 998-1000 the rotational displacement is corrected Any shortening is overcome by traction with



Fig. 1001 — October 6, 1941; Fig 1002, Fig. 1003 — December 16, 1941; Fig 1004, Fig. 1005 — February 18, 1943

Fig 1001 Double spiral fracture of the right humerus, in a 59-year-old seamstress who slipped and landed on her right arm. Immediate medullary nailing with screw traction apparatus (Fig. 998)

Figs. 1002 1003 Same as Fig 1001 after 10 weeks. Bony union in excellent position.

Figs. 1004 1005 Same as Figs 1002 and 1003 six months after removal of the nail and 16 months after injury The 2 fractures left only faint bone scars.

the screw In doing this, the lateral displacement and the angulation usually disappear in fractures of the middle third or these displacements can easily be corrected by manual pressure Biplane fluoroscopy will usually show good position of the fragments. Reduction is as a rule much more easily accomplished than on the femur or on the lower leg

Traction straps are then fastened to the four rotating bars If angulation persists it can be corrected by traction with these straps. If the fracture is in good position,

the straps are tightened for securing the fragments against slipping during the driving of the nail The elbow region is pulled backwards in order to become more accessible With Wittmoser s apparatus the fragments are immobilized by the two reduction rings.

Replacing the spring scale by a strong cord If the screw traction apparatus (Fig 998) was used, the spring scale must be replaced after reduction by a strong cord connecting the traction bow with the hook of the screw in order to eliminate the elastic give of the scale which would permit a displacement of the fragments during nailing

Irradiation damage during fluoroscopy must be avoided by following the rules given on page 37 (use of lead gloves, lead apron, short fluoroscopic exposures of 1–2 seconds)

The operation must not be started until the fragments are accurately reduced, because **good position of the fragments is an absolute essential for the smooth**



Figs. 1006–1009
February 17 1942

Figs. 1006–1009 Same as Figs 1001–1005 Photographs taken 4 months after injury Left the hospital after 3 weeks and resumed her work after 12 weeks.

progress of the operation and satisfactory healing The troubles which may arise from even slight angulations are evident from Figs 1038–1053

Sterile draping of the field The surgeon does not scrub until the fragments are well reduced and firmly secured The skin over the lower half of the upper arm is sterilized and draped with a split sheet

Incision A 3–4 cm incision is made through the skin and the tendon down to the bone 5–6 cm above the olecranon The tendon may be retracted to one side instead The wound is then held open by a small self retaining retractor The joint capsule above the olecranon fossa must not be opened.

Drilling the bone and inserting the awl Over the middle of the exposed bone surface a hole 6–7 mm in diameter is made with a round electric burr This opening is enlarged by oblique insertion of the awl (Figs. 992–995)

Application of the spring clip (Fig 76) This is applied for protection of the skin against pressure from the awl, the guide pin and the medullary nail A sterile pad is placed under it to prevent carrying loosened epithelium into the wound

Introduction of the measuring pin For accurate determination of the required length of the nail, a thin pin with rounded tip which has been measured accurately or which is marked with a centimeter scale is introduced. When it approaches the head of the humerus, it is propelled carefully under frequent short fluoroscopic checkups to prevent it from injuring the cartilage

X ray pictures X ray pictures are now taken from both sides. These must be 40 cm. long and not as short as in Figs 1024–1031, in order to provide a comprehensive view of the entire bone and of both joints, of the position of the fragments and the distance of the measuring pin from the shoulder joint. The central ray must be directed over the shoulder joint, to prevent the tip of the pin from appearing closer to the joint line than it actually is. The distance of the tip of the pin from the joint line and the length of the wire still protruding from the bone are measured. The length of the nail needed equals the distance from the shoulder joint to the opening in the bone, because the tip of the nail should reach to within 1½ cm. from the joint and should protrude 1½ cm from its point of insertion into the bone To avoid unnecessarily prolonged waiting for the X ray pictures, a rapid developer should be used (see page 35)

Driving of the double nail After the length of the nail has been accurately determined, it is introduced through the hole of the bone It must be held flat against the elbow during the driving so that it will not become caught on the anterior wall of the medullary canal (Fig 995) Since the tip is slightly bevelled, it slides along the anterior wall into the head (Fig 997) When it approaches the fracture site its progress must be checked by fluoroscopy in both planes. If the fragments were well reduced and secured it usually slides into the distal fragment without difficulty If not, the fragment must be slightly angulated or displaced slightly laterally Serious consequences may arise if it is angulated in the wrong direction (*Fig 1041*) *or too strongly* (Fig 1043) When the tip approaches the shoulder joint, both X ray tubes must be moved into that region. One must carefully see to it with short fluoroscopic exposures that the point does not penetrate into the shoulder joint (Fig 1090) The nail obtains its firmest anchorage in the epiphyseal zone (Figs 23–31)

Driving the nail from the shoulder If the fracture is located in the distal third it is preferable to nail from above (Figs. 1026–1029) In that case, the screw traction apparatus must be used without the 4 rotating rods otherwise the nailing site is not accessible The patient is positioned similar to Fig I/757 He must sit almost vertically and the upper arm must be brought 60–70° in front of the frontal plane instead of merely 30° as in this illustration.

The two X ray tubes are then set up and the arm is reduced with sufficient traction as in the nailing from below (see page 308) For securing the fragments, an accessory frame (Fig I/82) is attached to the apparatus above the middle of the upper arm and the fragments are then secured by straps in 2 3 or 4 directions, similar to Fig 803

Incision Starting at the lower border of the greater tubercle a 4–5 cm. longitudinal incision is made and carried distally through the deltoid muscle The soft tissues are held apart with a self retaining retractor

Since the cortex is very thin in this region (Figs 23, 24), it can easily be pierced with the awl and no burr is needed

The introduction of the guide pin,

The X ray pictures, and

The driving of the double nail is carried out in the same manner as in nailing from the distal end (see page 310) Since the cavity narrows distally in the sagittal plane, the inner thinner nail may be chosen 1 cm longer than the external nail

Skin suture and pressure bandage After the nail has been driven in, the skin is closed with a few sutures and covered with a pressure bandage to prevent hematoma.

X ray pictures After the nail has been driven and the wound closed, X ray pictures must be taken exactly from the front and from the side to determine the position of the fragments and of the nail at the fracture site and at the metaphysis Otherwise, incidents such as shown in Fig 1090, where the nail penetrated into the shoulder joint, might be overlooked

Straightening the bone If the arm was not firmly secured, an antecurvation de velops at the fracture because the nail is driven obliquely from behind forward (Fig 1067) This angulation can easily be corrected over a well padded wooden wedge

Impaction of the fragments If the fragments gape as in Figs 1068 1069 they must be impacted by blows with the palm of the hand upon the flexed elbow, other wise, callus formation is delayed and pseudarthrosis may develop

X-ray pictures Another set of X ray pictures must be taken from both sides after straightening and impacting the bones because the correction may have been too little or too much (Fig 1045) Straightening and checking by X ray pictures must be re peated until the humerus is straight in both planes and the fragments are well coapted and not gaping

Supplementary external support If a nail of sufficient length and thickness has been used, no additional plaster cast is needed If the fracture is still loose however a shoulder spica (Figs I/734 a–d) must be applied A cast on the upper arm alone (Figs. 392–394 E I/913–915) is insufficient as shown in Figs 1028 1029 A sugar tong splint to the upper arm (Figs 351 352 E I 752 753) is entirely inadequate as shown in Figs 1070–1073 If an added external support is needed either the in dication or the technique was defective Medullary nailing then loses its advantage of early exercises.

Post-operative positioning of the arm The arm is elevated on a pillow and a sling is used when walking If pain and swelling appear an abduction splint (Figs 65–67 E I/86–88) is used during the day for one to two weeks During the night, a pillow is used

Exercises The finger and the wrist joint must be actively moved through the full range from the first day Also rotation of the forearm must be practiced. Active motions of the elbow must not be permitted for one week until the swelling and the hematoma have subsided. If this joint is exercised in the first few days pain usually appears, the elbow becomes hot and the swelling recedes much more slowly Even inflammation at the fracture site or at the nailing site may ensue It must be em

phasized again and again that the elbow joint never suffers the slightest damage from an immobilization for one week, but does so by premature motions which as a rule cause pain

In the shoulder joint, motions may be carried out from the third or fourth day on as long as they cause no pain With his well arm the patient raises the injured arm to the horizontal

In the second week active exercises are begun in the shoulder and the elbow, provided they cause no pain The horizontal and vertical pulleys must not be used for exercises because they may produce a separation of the fragments.

Use of a sling In walking about, the arm must be carried for 2–4 weeks in a sling which, to be effective, must raise the elbow so as to prevent the weight of the arm from distracting the fragments.

Since marked stiffening, especially of the shoulder, frequently follows the carrying of the arm in a sling many call a sling the "burial sheet of the arm and want it eliminated. In my opinion, every painful arm should be carried in a sling However, it is necessary to exercise all the joints as outlined above Stiffening is not caused by the sling or by the patient who carries it, but by the one who neglects to see to it that proper exercises are carried out daily according to a plan.

Vigorous massage and passive motion The statement that these two measures are most deleterious in all fresh and most old injuries (see page I/37), holds true for medullary nailing as well That they may cause myositis ossificans and permanent stiffness especially at the elbow is shown in Figs I/37, 38 The rule

Exercises must never cause pain

(see page I/31) applies after medullary nailing as well.

Infection To date we have never had an inflammation follow a closed nailing of the humerus nor have others reported this complication.

Hospitalization We have discharged some patients from the hospital as early as 3–4 days after the operation if no particular swelling developed

Duration of treatment Work can be resumed after 6–12 weeks depending upon the location of the fracture and the age and occupation of the patient.

Subsequent observation After discharge from the hospital the patient must report for a check up at least once a week If the patient does not live too far distant, it is advisable for him to return daily or every other day for group exercises. After return to work the patient should report for an X ray check up every 2 months. A special file kept on all nailed cases serves to prevent overlooking the careful follow up (see page 54) which is most essential.

Extraction of the nail It is best to leave the nail *in situ* until the callus shows bony transformation This usually takes 4–6 months. If the nail is removed at a time when the fracture line is still plainly visible as in Fig 1016, the bone may again suffer a break during a vigorous motion If one waits long enough the extraction is very easy, even without an extraction instrument We sometimes do this under local anesthesia in the ambulatory patient.

Contingencies which may arise during closed medullary nailing of the humerus are evident from Figs 1040-1053 In Figs 1040, 1041, the nail penetrated postero medially through the proximal fragment and broke off a fragment of 8 cm because the reduction was not accurate and because a slight recurvation was left instead of producing a slight antecurvation This could have been avoided with continuous fluoroscopic control When another nail was inserted, too much antecurvation and a varus angulation were produced (Figs 1042, 1043) This caused such a bowing of the nail that it was kinked when the bone was straightened (Figs 1044, 1045) Besides the arm was bent so much that a slight recurvation (Fig 1045) was produced from the antecurvation This slight angulation was insignificant and should have been left, but instead, after 11 days the arm was again bent more than necessary This produced a varus angulation and a lateral displacement in both directions, the nail bent markedly and moved further upwards into the medullary cavity (Figs 1046–1047) The kinks in the nail and the lateral displacement now prevented an approximation of the fragments, and although a supplementary shoulder spica was used for 16 weeks, callus formation was delayed (Figs 1048–1053) The many months of immobilization caused a prolonged marked restriction of elbow and shoulder motions and a decided loss of strength Healing took much longer than with previous methods This proves that accurate reduction first and fluoroscopic observation of the nail during the driving are essential In straightening the arm, the proper strength must be used Fine discrimination and not brute force is what counts.

Another possible incident is the penetration of the nail into the shoulder joint (Fig 1090) this is possible if too long a nail has been selected or if a nail of proper length has been driven in too deeply Hart noticed radial paralysis in 2 cases (see page 86)

Delayed callus and globular callus of considerable degree (Figs 1014–1017 1028, 1029, 1060, 1061) are seen only if the nail is too thin or too short. The cause of this is discussed on page 90

Advantages of Küntscher s Medullary Nailing over Other Methods

In properly selected cases if this operation is performed at the right time (omission of operation during shock in the presence of swelling and open wounds) and with the proper technique (accurate reduction before driving the nail the use of a nail of sufficient length and thickness) better results are obtained than with the use of plaster splints or continuous traction Callus formation is not enhanced Local circulatory disturbances are less therefore there is also less wasting of muscles and less decalcification of the bone In cases which need no additional support, the motion is not disturbed Hospitalization is as a rule shorter and the end results are better

Causes of Failure in Closed Medullary Nailing of Fractures of the Humerus

1 **Operating under shock This may cause death** Medullary nailing is not an emergency procedure

phasized again and again that the elbow joint never suffers the slightest damage from an immobilization for one week, but does so by premature motions which as a rule cause pain

In the shoulder joint, motions may be carried out from the third or fourth day on as long as they cause no pain With his well arm the patient raises the injured arm to the horizontal

In the second week active exercises are begun in the shoulder and the elbow, provided they cause no pain The horizontal and vertical pulleys must not be used for exercises because they may produce a separation of the fragments.

Use of a sling In walking about, the arm must be carried for 2–4 weeks in a sling which, to be effective must raise the elbow so as to prevent the weight of the arm from distracting the fragments.

Since marked stiffening especially of the shoulder, frequently follows the carrying of the arm in a sling many call a sling the "burial sheet" of the arm and want it eliminated In my opinion every painful arm should be carried in a sling However, it is necessary to exercise all the joints as outlined above Stiffening is not caused by the sling or by the patient who carries it, but by the one who neglects to see to it that proper exercises are carried out daily according to a plan.

Vigorous massage and passive motion The statement that these two measures are most deleterious in all fresh and most old injuries (see page I/37), holds true for medullary nailing as well. That they may cause myositis ossificans and permanent stiffness especially at the elbow is shown in Figs I/37 38 The rule

Exercises must never cause pain

(see page I/31) applies after medullary nailing as well

Infection To date we have never had an inflammation follow a closed nailing of the humerus, nor have others reported this complication.

Hospitalization We have discharged some patients from the hospital as early as 3–4 days after the operation if no particular swelling developed.

Duration of treatment Work can be resumed after 6–12 weeks, depending upon the location of the fracture and the age and occupation of the patient.

Subsequent observation After discharge from the hospital the patient must report for a check up at least once a week If the patient does not live too far distant, it is advisable for him to return daily or every other day for group exercises. After return to work the patient should report for an X ray check-up every 2 months. A special file kept on all nailed cases serves to prevent overlooking the careful follow up (see page 54) which is most essential.

Extraction of the nail It is best to leave the nail *in situ* until the callus shows bony transformation This usually takes 4–6 months. If the nail is removed at a time when the fracture line is still plainly visible as in Fig 1016 the bone may again suffer a break during a vigorous motion *If one waits long enough the extraction is very easy, even without an extraction instrument* We sometimes do this under local anesthesia in the ambulatory patient

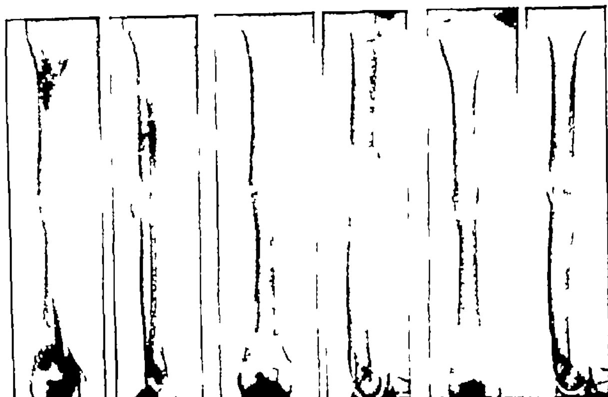


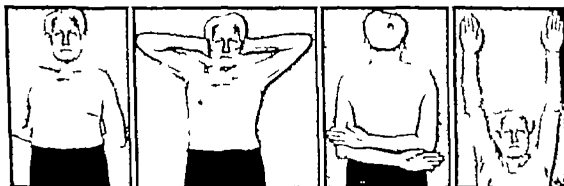
Fig. 1014 Fig. 1015 Fig. 1016 Fig. 1017 Fig. 1018 Fig. 1019

March 9 1942 May 12 1942 February 14 1943

Figs. 1014 1015 Same as Figs 1010–1013 8 weeks after medullary nailing. Since the nail was too short and too thin, there was play at the fracture site and a definitely globular callus developed (see page 134)

Figs. 1016 1017 Same as Figs 1012 and 1013 immediately after removal of the nail, and 4 months after injury Decidedly globular callus. The fracture line is still plainly visible especially in the antero-posterior view and extends through the callus.

Figs. 1018, 1019 Same as Figs 1010–1013 after 13 months. Bony consolidation The globular callus has receded.



Figs. 1020–1023

March 19 1942

Figs. 1020–1023 Same as Figs 1010–1019 9 weeks after injury Left the hospital after 14 days and resumed his occupation after 8 weeks.



Fig. 1010 Fig. 1011 Fig. 1012 Fig. 1013

January 15 1942 January 16 1942

Figs. 1010 1011 Transverse fracture of the right humerus just above the middle, in a 59-year-old book keeper who slipped in the snow and landed on his right arm

Figs. 1012 1013 Same as Figs 1010 and 1011 immediately after nailing in a screw traction apparatus (Fig 998) The fragments are in good apposition. The nail is too thin and too short. It is 8 cm. removed from the joint surface instead of 1–2 cm

2 Operating in the presence of swelling or fever Medullary nailing is not an emergency procedure

3 Operating before deep skin abrasions or wounds on the injured arm or in other parts of the body are completely healed (i e within 2–3 weeks) unless it was possible to operate within the first few hours Medullary nailing is not an emergency procedure

4 Operating in joint fractures

5 Operating in fractures which are less than 9 cm removed from the elbow

6 Operating without adequate armamentarium (sufficient selection of nails, retractors etc)

7 Operating without reduction apparatus

8 Operating with one instead of two X ray apparatus

9 Failure to use local anesthesia for the first X ray examination because the arm can then not be positioned properly especially for the lateral view

10 Neglect to determine accurately the length and width of the medullary canal

11 Failure to provide protection against heat loss

Open Medullary Nailing of Fresh Compound Fractures of the Humerus

In every compound fracture, the danger of infection is greater because the fracture site was exposed by the trauma The question is whether medullary nailing increases or decreases this danger I have usually rejected the old methods of osteosynthesis in compound fractures of the humerus, because they require wide exposure of the fragments and do not provide sufficient stability These two objections are not valid for Küntscher's medullary nailing For this reason, I used it formerly in fresh compound fractures of the humerus, if the local and general conditions permitted Now I use it only in rare instances because in case of infection, the entire medullary cavity becomes involved, whereas without nailing, the process remains localized Therefore, in markedly displaced fractures, I now sometimes use a wire suture without the medullary nail (Figs 1086, 1087)

If it is desired to perform open nailing, the procedure is as follows

General requirements with regard to the patient Medullary nailing must be performed only if the patient is in good general condition

Local requirements with regard to the bone All fractures which are at least 9 cm removed from the elbow may be nailed

Contra indications with regard to the patient If the general condition is poor (weak, rapid pulse pale appearance cold sweat) nailing must be omitted under all circumstances. **If the injured is in profound shock as usually happens in multiple injuries medullary nailing must positively be omitted or the outcome may be fatal**

If the general condition is poor a splint or a plaster cast, or, exceptionally, wire traction is applied

Contra indications with regard to the soft tissues and the bone In the first edition I wrote ' Marked contusion of the skin is no absolute contra indication Now I am of the opinion that the nailing should be performed only if the skin surrounding the wound is not injured or inflamed Fractures closer than 9 cm to the elbow should as a rule not be nailed because the nail does not provide sufficient stability

Preparation of the patient Since the patient is frequently severely shocked he must be well protected against further loss of heat and must be covered and rubbed with warm cloths and fortified with hot drinks

Detailed examination of the patient While the patient receives the foregoing attention for shock the type extent and depth of the injury should be determined accurately A pale or blue appearance of the fingers is noted and the condition of the circulation in them is checked Motion of the fingers and wrist sensation and the reflexes are tested. The pulse is frequently hardly palpable in shocked and exsanguinated patients. If it is absent on the injured side only it is a sign that the main artery is either torn or blocked by a clot or by the pressure from a fragment

First local anesthesia After this examination which should be done quickly, the fracture is anesthetized by the injection of 0 5 per cent novocaine solution between the fragments with the needle entering through healthy skin and not through the soiled wound With the elimination of pain the general condition usually improves and the pulse becomes stronger and slower (see case history page I/109)

12 *Failure to reduce fracture accurately*
13 Neglect to eliminate the give of the spring scale, after reduction and before the insertion of the nail, by a strong cord
14 Neglect to introduce the guide pin for measurement
15 Neglect to use fluoroscopy during the introduction of the measuring pin
16 Omission of X ray pictures after introduction of the measuring pin
17 Neglect to use the fluoroscope during the driving of the nail
18 Using the fluoroscope without lead gloves and lead apron.
19 Omission of X ray pictures after the insertion of the nail
20 Neglect to straighten the humerus
21 Neglect to impact the fragments
22 Neglect to apply a shoulder spica if the union of the fragments is not sufficiently stable
23 The application of a cast to the upper arm only (Figs 392–394 E, I/913–915) It does not provide sufficient stability
24 The application of a sugar tong plaster splint (Figs 351–352 E, I/752, 753) It does not provide sufficient support
25 Neglecting active exercises of the fingers, wrist and forearm through the full range from the first day on
26 Premature exercises of the elbow i e during the first week
27 Using the horizontal and vertical pulleys for exercises, this may cause separation of the fragments
28 Use of vigorous massage and forcible passive motion This produces limitation of motion in the elbow and sometimes myositis ossificans
29 Omission of subsequent observation and X ray control before the fracture is firmly united and the nail removed
30 Neglect to use a special file for nailed cases
31 Premature extraction of the nail.
32 Neglect to take X ray pictures at the conclusion of the treatment

Rejection of Open Medullary Nailing of Fresh Closed Fractures of the Humerus

With the use of our reduction apparatus (Figs 998–1000) we have always succeeded in reducing closed fractures of the humerus in such a way that closed nailing was possible

If in an exceptional case reduction should prove impossible the fragments should not be exposed for nailing or else the outstanding advantage of Küntscher's method is lost In fresh closed fractures this consists of the fact that only a small wound need be made far removed from the fracture site

Such cases must be treated with plaster casts or splints or exceptionally with wire traction The dangers of the old operative treatment of fresh closed fractures with exposure of the fracture field are discussed on pages I/152 153

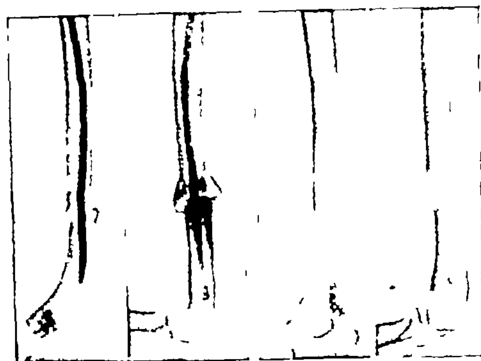


Fig 1028 Fig. 1029 Fig 1030 Fig. 1031
February 4 1942 July 15 1942

Figs. 1028, 1029 Same as Figs 1024–1027 eleven weeks after medullary nailing Strikingly large globular callus, because the nail is too thin and too short. The fragments therefore had play in spite of the arm cast. The fracture line is plainly visible in the lateral view and continuous through the callus.
Figs. 1030, 1031 Same as Figs. 1024–1027 eight months after medullary nailing and immediately after extraction of the nail Bony consolidation. The globular callus has receded.

The *length and width of the medullary canal are measured* in the manner described on page 305 this determines the length and thickness of the nail required

Personnel One assistant is needed for the debridement, and another one for the supervision of the patient (appearance, pulse and possibly general anesthesia) an instrument nurse and an X ray technician are also needed

Second local anesthesia For the wound excision local anesthesia is most satisfactory A 0 5 per cent solution of novocaine is infiltrated into the soft tissues as far as they are torn and also into the nailing site For the nailing a short general analgesia is sometimes required

Protection against heat loss The patient must be well covered as for any operation

Wound excision If the patient comes under our care within the first 6–8 hours the wounds are thoroughly excised according to the rules given on pages I 106–130 where the procedure for skin, fascia muscles tendons blood vessels nerves and the bone is described in detail

The wounds often have to be extended by longitudinal skin incisions in order to reach and remove all the torn and soiled tissues *The skin must never be cut transversely* even if the original wound was transverse or else the retracted muscle stumps will not be found This is particularly true of those muscles which have retracted towards the elbow region All tissues deprived of circulation must be



Fig. 1024 Fig. 1025 Fig. 1026 Fig. 1027
November 16 1941 December 4, 1941

Figs. 1024 1025 Transverse fracture of the left humerus between the middle and distal third, 11 cm. above the elbow in a 38-year-old railroad worker who was run over Simultaneous fracture of both forearm bones at the middle.

Figs. 1026 1027 Same as Figs 1024 and 1025 two weeks after operation. The nail was inserted from the proximal end. Its tip is 5 cm. removed from the joint. At the same time double wire transfixion cast to the forearm.

Infusion and transfusion If the patient does not recover by warming hot drinks and local anesthesia, he is given an infusion of 500 cc. of an isotonic solution of blood serum salts, and preparations are made for a blood transfusion.

X-ray pictures If the patient responds to this treatment with improvement X ray pictures are taken in both planes to determine the type and extent of the bone injury The films must be at least 40 cm long to show both joints

Amputation If the injured arm remains without sensation cold and pale and if the circulation does not return after pressure upon the finger nails although the patient has recovered, the arm must be amputated in time if possible within the first 6–8 hours so that the stump may be closed safely Patients sometimes refuse amputation because they can still move the fingers This, however does not indicate survival of the arm because motions are still possible within the first few hours if the nerves are not severed.

Time of nailing Nailing may as a rule be performed only within the first 6–8 hours as long as no inflammatory reaction has set in. If the operation is performed later an infection of the medullary cavity may ensue

Instrumentarium For open nailing the instruments shown in Figs 85–91 are needed in addition to those required for closed medullary nailing as listed on pages 22–26 A reduction apparatus and a second X ray apparatus are not required



Fig 1032 Fig 1033 Fig 1034 Fig 1035 Fig 1036 Fig 1037

March 23 1944 March 27 1944 May 4 1944

Figs. 1032, 1033 Transverse fracture of the left humerus just above the middle of the shaft in a case of Paget's disease with narrow medullary cavity and typical smooth fracture surfaces. Both fragments appear very short in the A P view because of foreshortening from angulation. Suffered by a 51 year-old goldsmith who fell on an icy street

Figs. 1034 1035 Same as Figs 1032 and 1033 after the operation which was performed 4 days later under plexus anesthesia with Wittmoser's reduction apparatus (Fig 1000) with a thin but sufficiently long medullary nail. A drain is located at the nailing site. The fragments are in good apposition and well impacted. Was merely given a triangle sling. Discharged from the hospital after 14 days. Full active motion of fingers, wrist and forearm elbow 70–150° lateral shoulder elevation 105 Outward rotation restricted by one third Inward rotation free

Figs. 1036, 1037 Same as Figs 1034 and 1035 after 6 weeks The fracture line has become wider Beginning globular callus. Full active motion in all joints of the arm. Resumed his work after 9 weeks.

Removal of the plaster cast In fractures of the middle third in good position, if the fragments were firmly joined by the operation the cast may be removed after 3 weeks In fractures close to the joints the cast is removed from the dorsal surface of the hand and forearm after 3 weeks to permit active motion in the wrist joint and active rotation of the forearm In these fractures the cast is removed completely after 5–6 weeks

Vigorous massage and forcible passive motion are particularly contra indicated in compound fractures because they may bring about late infection and myositis ossificans

Again the old rule holds true (see page I/31)

Exercises must never cause pain

carefully excised, preserving larger blood vessels and nerves. From these only the soiled adventitious tissue is removed The bones are cleaned of dirt with a rongeur and with hammer and chisel Fragments still connected with the periosteum must not be removed A thorough debridement often takes an hour or more

Blood transfusion If the pulse and the general appearance have not improved in the meantime, 400–500 cc of blood are transfused

Application of splint, cast or traction If the general condition does not improve following the blood transfusion, a splint, a cast or continuous traction is applied.

Open medullary nailing If the general and local conditions are good, medullary nailing may be performed.

The skin incision above the elbow or below the shoulder,
the application of the spring clip,
the piercing with the awl,
the introduction of the guide pin for measuring, and
the X ray pictures, are all carried out in the same way as in closed fractures of the humerus (see pages 309, 310)

Driving of the nail When the accurately measured double nail reaches the fracture the fragments are held together with Lambotte clamps (Fig 85) to permit easy entry of the medullary nail into the other fragment.

X ray pictures After the nail is completely inserted X ray pictures must again be taken in both planes

Supplementary wire suture If the X ray pictures show good position a drill hole is made into both fragments in transverse fractures and a longitudinal wire suture is applied (Figs. 478 479, 1076–1081), in spiral fractures one or two circum ferential wire sutures are applied (Figs. 1084–1087) Without such supplementary wire sutures, the fragments in compound fractures might separate, as in Figs 1068 1069

Insertion of drains After the wire sutures 1–3 rubber drains are inserted into the deepest part of the wound carried out through healthy skin, and fastened with a suture

Wound closure If the wounds are not older than 6–8 hours, the skin and the skin only is closed with sutures No ligatures (see page I/113) and no sutures are buried An exception to this rule is made only in case of severed nerves

Application of pressure bandage The wound and the nailing site are provided with a light pressure bandage to prevent hematoma

Application of a plaster cast For immobilization of the soft tissue wounds, either a cast is applied to the upper arm (Figs 392–394 E I/913–915) or, depending upon the location of the fracture a shoulder spica (Figs. I/734 a–d) these bandages are split and fenestrated immediately

Removal of drains and open wound treatment After 24–36 hours the pressure bandage and the drains are removed. The wound remains uncovered and the drain opening is covered with a small sponge

Exercises The fingers are exercised actively through the full range from the first day



Fig. 1042 Fig. 1043
August 20 1943

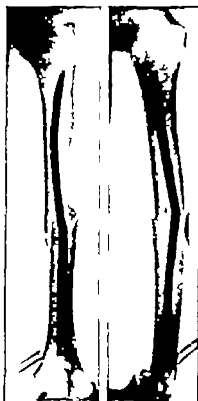


Fig. 1044 Fig. 1045
August 20 1943



Fig. 1046 Fig. 1047
September 1 1943



Fig. 1048 Fig. 1049
October 18 1943

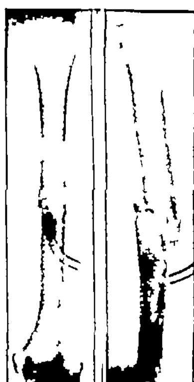


Fig. 1050 Fig. 1051
December 7 1943

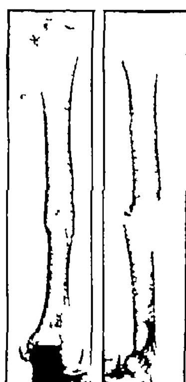


Fig. 1052 Fig. 1053
January 20 1945



Fig. 1038 Fig. 1039 Fig 1040 Fig 1041

August 20 1943 August 20 1943

Figs. 1038 1039 Leverage fracture of left humerus below middle with small wedge fragment posteriorly marked displacement of fragments and simultaneous dislocation of left humerus at the shoulder joint downward and forward. In a 44-year-old printer who was knocked off his motorcycle by a truck.

Figs. 1040 1041 Same as Figs 1038 and 1039 after reduction of shoulder under general anesthesia, easily accomplished by Hippocrates method and after insertion of a double nail with the reduction apparatus of Fig 998. Since a recurvation persisted the nails perforated the proximal fragment and protruded into the soft tissues behind In so doing, the nails broke an 8 cm. long splinter off the lateral wall.

Figs. 1042 1043 Same as Figs 1040 and 1041 after insertion of a new double nail with antecurvation of 25 and varus of 15° The nail is too short. It is 6 cm. removed from the joint instead of 1–2 cm.

Figs. 1044 1045 Same as Figs 1042 and 1043 after straightening the bone. There is now a varus of 5° and a recurvation of 10° The nail is bent at the fracture site. Arm placed on airplane splint.

Figs. 1046, 1047 Same as Figs. 1044 and 1045 after an attempt to correct recurvation on the 11th day This caused a varus of 15° and a lateral displacement of the distal fragment forward and inward. The nail has a double kink and has slipped upward by 2.5 cm The head of the nail slipped into the medullary cavity A shoulder spica was applied after correction of the angulation.

Figs. 1048, 1049 Same as Figs 1046 and 1047 after 7 weeks and 8 weeks after the accident. Good alignment in both views No callus formation between the main fragments. Some cloudy callus shadows between the wedge and the distal fragments.

Figs 1050, 1051 Same as Figs 1038–1049 immediately after removal of the medullary nail which required the chiseling of a 5 cm. long groove into the bone, and 16 weeks after injury No periosteal callus visible. The callus bridge between the wedge and the distal fragments has become stronger

Figs. 1052 1053 Same as Figs 1038–1049 after 17 months. Bony consolidation. All joints of the arm actively free since August, 1944 After 8 months, motion at the elbow was only 170–60° against 180–45° on the right lateral shoulder abduction 130° against 160° on the right. Had some difficulty in putting his hand on the back of his head and over the sacrum. If this fracture had been treated after reduction, without nailing, with an abduction splint (Figs. I/741–746) or with a shoulder spica (Figs. I/734 a–d) it would have probably been firm after 8 weeks and full motion restored after 3 months.

great resistance The tissues are torn and this later limits motion Nerve and vascular disturbances following rapid correction of shortening are much less common on the humerus than on the femur because the shortening is never as great With prolonged duration of the operation, asepsis may be disturbed and infection may occur in the torn tissues For these reasons, the shortening must be corrected before the operation

Indications for medullary nailing of old fractures of the humerus The main indications are delayed callus formation due to marked lateral displacement (Figs 1054, 1055), or to excessive traction

Contra indications for medullary nailing of old fractures of the humerus

1 Poor general condition All internal organs, especially those of circulation must be normal
2 Age over 40 years Only exceptionally should older people be operated upon
3 Local inflammatory processes of the bone Sinuses must have been closed for at least 6 months
4 Marked decalcification of the bones combined with circulatory disturbances Dystrophic limbs are particularly liable to post operative infections
5 Skin pathology (inflammation, extensive scars adhering to the bone)
6 Shortening of more than 3 cm This must be corrected first by continuous traction
7 Extensive ossifications in the medullary cavity
8 Marked impairment of the muscles and the joints

Correction of the shortening by continuous traction following closed refracture A shortening of more than 3 cm must be overcome before operation Fibrous union between the fragments must be disrupted by manipulation over a wooden wedge (Figs. 868 E II 2488) or with a Phelps-Gocht osteoclast (Figs 934 E II/2746) Wire traction with 3–4 Kg weight is then applied to the ulna just below the olecranon (Figs 364 E I/747) After 2 days the weight is gradually increased until the shortening is abolished In Figs 1054, 1055 traction with 5 Kg was required to remove the shortening in 12 days It is better to use more weight to obtain the correction in a shorter period of time

Open medullary nailing of old fractures of the humerus Only after the shortening has been corrected or if no shortening existed may one proceed with the nailing

The length and width of the medullary canal are determined as in closed fractures of the humerus (see page 305)

Anesthesia Plexus anesthesia serves best (see page I 101)

Exposure of fragments These are exposed through a lateral incision and freshened obliquely or Z-shaped because in transverse freshening callus is delayed The radial nerve must be carefully protected The periosteum is elevated as little as possible because this may lead to the formation of large sequestra (Figs 511–513, 515–524) if the healing of the wound is disturbed The operation is easiest if no callus has yet formed as in Figs 1054–1055 In that case it is sufficient to freshen the fragments with a sharp chisel whereupon they can be approximated accurately and without difficulty

Removal of sutures If the wounds heal without complications, the sutures should not be removed for 3 weeks They must be removed immediately to open the wound widely if fever redness and swelling appear

The subsequent observation,

the keeping of a special record and

the extraction of the nail, are carried out in the same manner as in closed fractures of the humerus (see page 312)

Results All five fresh compound fractures of the humerus which we have nailed to date, healed without complications The results therefore are as good as those obtained in our 24 compound humeral fractures previously reported in Ehalt's book, all of which healed without wound disturbances The treatment is simplified but potentially more dangerous

Open Medullary Nailing of Fresh Gunshot Fractures of the Humerus

In contrast to gunshot fractures of the femur, it is rather easy to immobilize gun shot fractures of the humerus by a plaster cast For this reason there is no urgent necessity to use a medullary nail and I would advise against it.

Open Medullary Nailing of Infected Gunshot Fractures of the Humerus

I had the opportunity to see a considerable number of gunshot fractures of the humerus which had been nailed elsewhere in the presence of sinuses In most cases prolonged suppuration followed which remained bland and never led to a phleg monous process in the medullary cavity However, I gained the impression that the healing was not accelerated, but rather delayed by the use of the nail and that for this reason the function was poorer than in non nailed cases.

Häbler recommends medullary nailing even in infected fractures. His advice should not be followed until he reports on a continuous series of a number of cases, thoroughly followed up which prove definitely that nailing shortens the period of treatment and that the results are satisfactory

Open Medullary Nailing of Old Fractures of the Humerus

Shortening and angulation cause much less disturbance in humeral fractures than in fractures of the femur or of the lower leg Nevertheless marked angulations should be corrected if this is possible without endangering the patient.

Küntscher s medullary nailing has the advantage that in selected cases (Figs 1054–1063) and with correct technique no redisplacement can occur and the joints can be exercised early

The procedure is never an emergency one Therefore it should be resorted to only if the patient is in good general condition the skin is healthy and if the shorten ing is less than 3 cm If the skin shows any diseased condition one must wait until it has been normal for 2 months. In the presence of extensive scars adhering to the bone one must forego medullary nailing entirely

If an attempt is made to correct a shortening of more than 3 cm during the the operation, much force and time is used because the contracted muscles offer



Figs. 1058, 1059 Same as Figs 1054–1057 after open medullary nailing Application of abduction splint. The nail is too short.

Figs 1060 1061 Same as Figs 1058 and 1059 after 3 months. The fragments separated slightly because no supplementary wire suture and no shoulder spica was used. Fracture line continues through the globular callus (see page 134)

Figs. 1062, 1063 Same as Figs 1058–1061 immediately after removal of the nail and 8 months after the operation. Firm bony union. The excess callus has been absorbed. All joints actively free

coaptation of the fragments with Lambotte clamps,
application of supplementary wire sutures,
insertion of drains
skin suture and pressure bandage
removal of drains
exercises
removal of sutures and
subsequent observation

If the fragments are well coapted and a wire suture is applied, no shoulder spica is needed for fractures in the middle third

Rejection of Open Medullary Nailing in Pseudarthroses of the Humerus

Pseudarthrosis of the humerus as a rule does not cause such serious disturbances as that of the femur and lower leg Since the strength of the arm is however greatly impaired by this condition we attempt to correct it if the local and general condition of the patient permit

Causes of pseudarthrosis In compound fractures the removal of fragments was the most prevalent cause especially if the remaining fragments were subsequently



Fig. 1054 Fig. 1055 Fig. 1056 Fig. 1057

August 31 1942 September 12, 1942

Figs. 1054 1055 A 4-weeks-old transverse fracture of the middle of the right humerus, in a 31 year-old man who was run over Shortening 4.5 cm.

Figs. 1056 1057 Same as Figs 1054 and 1055 after wire traction through the olecranon with 5 Kg for 12 days. The shortening disappeared.

Guide groove If the fragments are absorbed, a guide groove, 5–6 cm long and 1–2 mm deep and wide is chiseled into both fragments before they are severed This groove provides a guide for the prevention of rotatory displacement or for its correction

Procedure with pus foci If a cavity filled with granulation tissue or pus is met during the exposure of the fragments, the operation must be discontinued It should not be performed later

Exposure of the medullary cavities If these are not patent after freshening they must be opened with the awl

The subsequent procedure is the same as in closed or compound fractures of the humerus (see pages 309 and 320) viz

incision for nailing

application of the spring clip

drilling the bone with a round burr and widening the hole with the awl in the distal third

piercing the bone with the awl in the proximal third

introduction of the measuring pin

X ray pictures

rapid development

driving the nail



Figs 1058 Fig 1059 Fig 1060 Fig 1061 Fig 1062 Fig 1063

September 15 1942 December 7 1942 May 15 1943

Figs 1058 1059 Same as Figs 1054 1057 after open medullary nailing. Application of abduction splint The nail is too short

Figs 1060 1061 Same as Figs 1058 and 1059 after 3 months. The fragments separated slightly because no supplementary wire suture and no shoulder spica was used Fracture line continues through the globular callus (see page 134)

Figs 1062, 1063 Same as Figs 1058–1061 immediately after removal of the nail and 8 months after the operation Firm bony union The excess callus has been absorbed All joints actively free

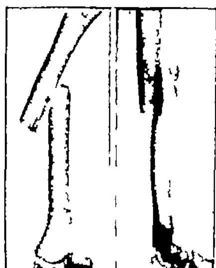
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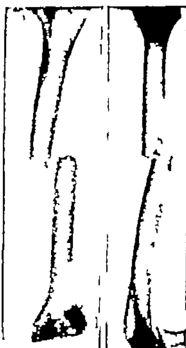


Fig 1054 Fig 1055 Fig. 1056 Fig. 1057
August 31 1942 September 12 1942

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incision for nailing
application of the spring clip
drilling the bone with a round burr and widening the hole with the awl in the distal third
piercing the bone with the awl in the proximal third
introduction of the measuring pin
X ray pictures
rapid development
driving the nail

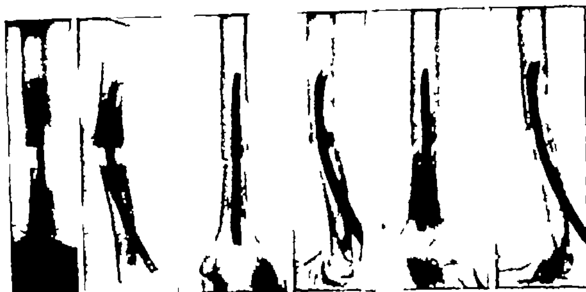


Fig 1068 Fig 1069 Fig 1070 Fig 1071 Fig 1072 Fig 1073
July 29 1942 September 28 1942 January 22 1943

Figs. 1068 1069 Same as Figs 1066 and 1067 three days after operation The fragments separated by 16 mm After their impaction, a shoulder spica was applied (Figs 1/734 a–d)

Figs. 1070 1071 Same as Figs 1068 and 1069 after 2 months. Beginning callus formation. Shoulder spica was removed and replaced by a sugar tong splint to the upper arm.

Figs. 1072 1073 Same as Figs 1070 and 1071 after 4 months. The fragments have again separated slightly Callus slight only posteriorly Fracture still loose Therefore on March 2 1943 i.e 9 months after the first operation a second nailing and wire suture as in Figs 1076–1081 and shoulder spica for 14 months. The fracture line was then partly bridged If the fragments had been freshened obliquely and united with 2 circumferential wire loops and immobilized with a cast from the knuckles to the shoulder the pseudarthrosis would probably have united in 10–12 week

In pseudarthroses with such a high degree of decalcification of the entire humerus that the cortex is only paper thin medullary nailing has failed just as badly as the transplantation of massive grafts which are as a rule absorbed within a few weeks or months

With medullary nailing the danger of an infection involving the entire medullary canal is ever present whereas with previous methods it remained confined to the fracture stumps

For the reasons just mentioned I no longer use medullary nailing in the treatment of pseudarthroses of the humerus and advise against it

Those who wish to perform it nevertheless must proceed as follows

Oblique or Z shaped freshening of the fragments is indispensable With transverse freshening callus production will be delayed or even pseudarthrosis may recur The medullary canal must be patent on both fragments I have seen many cases of failure because freshening was omitted through reliance upon the callus-stimulating effect of the medullary nail (Figs 468–477) Several cases were sent to me with a broken medullary nail as in Figs 476 477 Figures 478 479 show that even this bone unites firmly in a short time following thorough freshening of the fragments and wiring



Fig 1064 Fig. 1065 Fig. 1066 Fig. 1067
June 23 1942 July 26, 1942

Figs. 1064 1065 A 7-months-old tight pseudarthrosis of the left humerus in a 22 year-old man following closed transverse fracture caused by too brief immobilization, early massage and forcible passive motion Figs. 1066 1067 Same as Figs. 1064 and 1065 after operation Both fragments were freshened transversely The nail is too short. No wire suture. The fragments are in excellent apposition. Plaster cast from finger knuckles to shoulder (Figs. 392 E I/913)

distracted by continuous traction instead of being pushed together in a plaster cast Figs 1088 1089)

It also follows premature interruption of the immobilization for the sake of applying massage and passive motion (Figs 1064 1065 1082 1083)

At the present time the most common causes of pseudarthrosis in closed and compound fractures of the humerus are wire traction either with too heavy weights or with springs (Figs 289 290 and 468 469) and a shoulder spica applied under too strong traction (Figs. 366–372 and page 120) With adhesive plaster traction on the abduction splint (Figs 349 350 E I 589, 590 and I/741–746) we never had a pseudarthrosis develop in closed fractures

Pseudarthrosis will rapidly become much rarer if traumatic surgery is organized as suggested on pages II 1525–1530 and if independent institutions are established for its teaching and practice

Nailing For some time we used medullary nailing in most pseudarthroses of the humerus because we gave credence to the original assertions in the literature that the medullary nail has a callus-stimulating effect which is the very object in the treatment of pseudarthroses since they are due to the exhaustion of the callus-forming capacity A critical evaluation of the results in humeral pseudarthroses treated by us and others with medullary nailing forces me to the conclusion that this method offers no advantages over others but entails great disadvantages. The production of callus is not enhanced by the nail but frequently retarded This is true particularly in transversely freshened cases in which no supplementary wire suture is applied (Figs. 1064–1073)

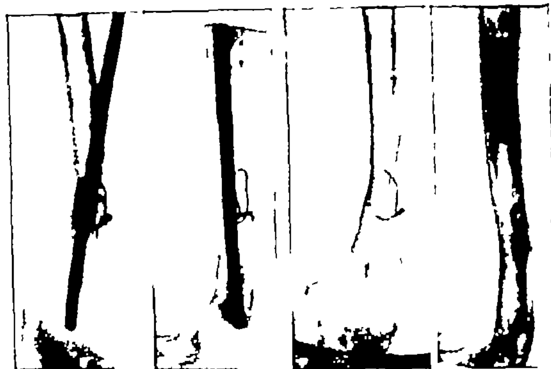


Fig. 1078 Fig. 1079
October 6, 1942

Fig. 1080 Fig. 1081
January 28, 1943



Fig. 1082 Fig. 1083
April 1 1942

Fig. 1084 Fig. 1085
June 1 1942

Fig. 1086 Fig. 1087
February 9 1943



Fig 1074 Fig 1075 Fig. 1076 Fig 1077

April 23 1942 June 4 1942

Figs. 1074 1075 An 11 months-old pseudarthrosis of the left humerus in a 35-year-old man, from an automobile accident. The closed fracture was sutured *elsewhere* immediately with 2 wire loops. Infection and paralysis of the radial nerve followed. After 1 month the wires were removed. After 4 months the wound closed. Sclerosed pseudarthrosis. Bones decalcified

Figs 1076 1077 Same as Figs 1074 and 1075 immediately after the operation and 6 months after closure of the wound. Both fragments were freshened transversely The nail perforated the thin cortical bone. With a longitudinal wire loop the 2 fragments are held together The nerve was sutured after resection of the thickened ends. Shoulder spica for 4 months.

Figs 1078 1079 Same as Figs. 1076 and 1077 four months after operation. Firm bony union.

Figs 1080 1081 Same as Figs 1076–1079 immediately after removal of the nail and 8 months after operation The fragments show bony union The wire loop was left. Radial paralysis not improved. If the fragments had been freshened obliquely instead of transversely and united with 2 circumferential wire sutures by perforating and encircling the bones 1 times and a cast had been applied from the knuckles to the shoulder this pseudarthrosis would probably have united in 10–12 weeks by a much simpler and less dangerous procedure.

Figs 1082 1083 Oblique pseudarthrosis of the right humerus in a 28-year-old man from shell fragments. *Condition 8 months after injury and 5 months after closure of wounds Radial paralysis*

Figs. 1084 1085 Same as Figs 1082 and 1083 2 months after exposure and freshening of the fragments. The radial nerve was dissected from the surrounding scars and sutured. After insertion of the nail, the fragments were united with 2 wire loops. Eight days after operation he was able to raise the arm well and to move the elbow After 8 weeks, firm bony union.

Figs. 1086 1087 Same as Figs 1082 and 1083 immediately after extraction of the nail and 10 months after operation Bony consolidation. The 2 wire loops were left. Active extension of fingers. If only 2 wire loops had been used without the nail this pseudarthrosis would have united just as quickly



Fig. 1092 Fig. 1093 Fig. 1094 Fig. 1095 Fig. 1096 Fig. 1097
May 3 1943 October 9 1943 January 17 1944

Figs. 1092, 1093 Same as Figs 1088–1091 five months after operation The bone graft did not take

Figs. 1094 1095 Same as Figs 1092 and 1093 immediately after removal of the nail and 10 months after insertion Fracture still loose The graft sequestrates.

Figs. 1096, 1097 Same as Figs 1088 and 1089 after 14 months. The transplanted necrotic bone graft was removed. The defect is now much larger and the arm shorter than before the nailing. In such cases a massive bone graft long enough to overlap both bone fragments by 4 cm. as in Figs 200–203 E, I/283–286 must be used

use medullary nailing in humeral pseudarthroses, particularly because a possible infection may spread to the entire medullary canal

Rejection of Open Medullary Nailing of Defect Pseudarthrosis of the Humerus

Relying upon callus-stimulation by the medullary nail some surgeons have used it in defect pseudarthrosis of the humerus Only failures have resulted, not only in those cases in which the fragments were brought together but particularly also in those in which the gap was left open Bone defects can be bridged only with fresh bone grafts preferably from the well tibia Both fracture stumps must be freshened for a distance of 4–5 cm so as to provide a broad area of contact with the transplanted bone which must therefore be at least 8 cm longer than the gap between the fragments Figures 196–203 E I 279–286 prove that such grafts take well

Figures 1090–1095 show that a nail used with a short graft with only 0.5–1 cm contact with the fragments does not lead to bony union

If bone grafts of sufficient length are used adequate stability is obtained for the application of a shoulder spica The medullary nail can do only harm because it destroys the bone marrow in the very places where the graft makes contact



Fig 1088 Fig 1089 Fig. 1090 Fig. 1091

November 26, 1942 December 5 1942

Figs. 1088, 1089 Defect pseudarthrosis of the right *humerus*, in a *31 year-old blacksmith following* an infected comminuted gunshot fracture which was treated with excessive adhesive plaster traction and a shoulder spica.

Fig. 1090 Same as Fig 1088 after exposure of the fragments *elsewhere* removal of eburnated fragment, insertion of nail and transplantation of a tibial graft which was too short. Four drill holes can be seen in the graft through which the suture material was drawn to fasten it to the medullary nail. The nail protrudes into the shoulder joint.

Fig 1091 Same as Fig 1089 The nail has been retracted from the shoulder joint. The head of the nail is close to the elbow

Supplementary wire sutures In all pseudarthroses the muscles are greatly impaired by the injury as well as by the prolonged treatment and they are therefore unable to hold the fragments together The weight of the forearm and of the distal fragments consequently pulls them apart To prevent this, the fragments must after freshening and medullary nailing definitely be held together by longitudinal or transverse wire sutures (Figs 478 479 1076–1081 1084–1087) Figures 1068 and 1069 show how the fragments separate if no wire sutures are used

Shoulder spica Since the capacity of the bone to produce callus is markedly impaired in all cases of pseudarthrosis a thorough freshening of the fragments wire suturing and the use of a sufficiently long nail are insufficient, and a shoulder spica is required for 8 weeks for complete immobilization (Fig I/734 a-d) This however cancels all advantages of medullary nailing because in a spica the joints cannot be exercised early

Since I have usually attained more rapid healing by merely thorough freshening of the fragments and a wire suture, or by a bone graft, I no longer

the swelling has disappeared If *tension blebs* have developed as a sign of marked interference with the circulation, then nailing must be omitted

Contra indications with regard to the bone Comminuted fractures and fractures in diseased bones in which the medullary cavity is filled, are not suited for nailing

In *fractures with angulations without lateral displacement*, as in Figs I/974–977 and I/988-995, nailing is superfluous, because good position can be maintained with a cast alone

Fractures of the olecranon are, as a rule, not suitable for medullary nailing They are best repaired with a longitudinal wire suture (Figs I/889-894 and I/898-901)

Fractures of both forearm bones less than 6 cm removed from the joint are not suitable Isolated fractures of the ulna must be at least 3 cm removed from the proximal and 6 cm from the distal end Isolated fractures of the radius must be at least 5 cm distant from the proximal and 10 cm from the distal end

Local anesthesia and X ray pictures Satisfactory bi plane X ray pictures of sufficient size are indispensable for medullary nailing For proper positioning of the forearm it is desirable to anesthetize the fractures by local anesthesia (see page I 99) The pictures must be at least 30–40 cm long for a good survey and to avoid overlooking other injuries especially a dislocation of the radius at the upper or distal end (Figs 1117 1172–1179, 1180–1185 1186–1197) and also for accurate measurement of the width of the entire medullary canal The views must include the elbow joint, wrist joint and both radio ulnar joints (Figs 1103–1106)

Time of operation If the general condition is good, one may operate within the first few hours. The fragments can most easily be reduced on the first day before the hematoma and swelling become too large If for some reason it was not possible to perform the nailing within the first few hours it may be performed during the next few days if the swelling is only slight If it is marked causing glossy skin and even tension blebs one must not operate nor in the presence of deep abrasions In the presence of wounds on the broken arm or on other parts of the body, nailing must be delayed Unless one can do it immediately after debridement, one must wait until all wounds are well healed i e , at least 2–3 weeks, or else they may break open and lead to metastatic infection at the fracture site (see page 151)

Determination of the length and width of the medullary canal After the X ray pictures are finished and the time for the operation has been set, the length of both bones is measured on the well arm This is very simple and reliable because the bone ends can always be readily palpated with the elbow flexed at a right angle The nail should as a rule be 3–6 cm shorter than the fractured bone yet it must not be too short The majority of disturbances are due to the use of too short a nail frequently inserted at the incorrect site (Figs 460–467 1129–1132 1174–1177, 1200–1201)

The width of the canal is determined from the X ray pictures In adults the narrowest area in the middle third varies from 2–5 mm Towards the proximal and distal ends the canal widens slightly (Figs 34–42 and 45–53)

Armamentarium This is listed on pages 22–26 and is illustrated in Figs 67–107 In addition one needs several guide wires of 1 5 mm thickness and 15–30 cm in length with a fitting handle (Figs 81 82) and a self retaining wound retractor

FRACTURES OF THE FOREARM BONES

Closed Medullary Nailing of Forearm Fractures

At the outset it must be stated that closed medullary nailing is a very difficult procedure in closed forearm fractures.

General requirements with regard to the patient Nailing is permissible only if the patient s general condition is satisfactory Heart, lungs, kidneys reflexes, motions of the joints, and sensation must therefore be examined carefully The skin must be in good condition and must show no inflammation, not even outside the fracture area No inflammatory process must be present in any other part of the body (e g tonsillitis)

Local requirements with regard to the patient Most suitable are transverse fractures of both bones at least 5–6 cm removed from the joints (Figs 1101–1104, 1105–1110) Fractures of the ulna must be at least 3 cm distant from the proximal end and 6 cm from the distal end, isolated fractures of the radius must be removed at least 5 cm from the proximal and 10 cm from the distal end Fractures closer to the distal end of the radius (Figs 1117, 1118) are not suited for closed medullary nailing

Contra indications with regard to the patient If the general condition is poor (weak, rapid pulse pale appearance, cold sweat), nailing should positively not be performed because it is no emergency procedure **If the patient is in shock, as is usually the case in multiple injuries, medullary nailing must absolutely be omitted, or the outcome may be fatal** (see also page 8) I am repeating this sentence in every chapter because many beginners, in their enthusiasm for the new method see only the broken bones and not the patient With a poor general condition only a plaster cast or a splint may be used. Continuous traction is to be rejected because it frequently leads to pseudarthrosis, especially if skeletal traction is used

Contra indications with regard to the soft tissue Inflammatory conditions of the respiratory digestive or genito-urinary organs constitute a contra indication against medullary nailing because of the danger of hematogenous infection of the bone marrow Particular attention should be paid to tonsillitis

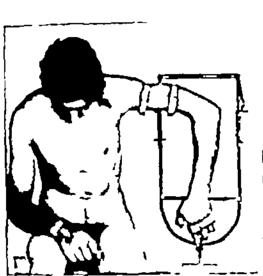
In *inflammatory conditions of the skin* especially *furunculosis* medullary nailing must be omitted because of the danger of metastatic spread.

In the presence of *burns* especially on the injured limb nailing should not be done

In the presence of *wounds on other parts of the body* nailing must not be performed until they are entirely healed hence at the earliest 14 days after injury otherwise, late infection and spreading of germs may follow (see page 151)

In the presence of *deep abrasions* over the fracture nailing must be avoided because sloughing of the crushed skin may expose the fracture sites and lead to infection of the rather superficially located bones of the forearm

In the presence of *marked swelling* nailing is not advised One must wait until



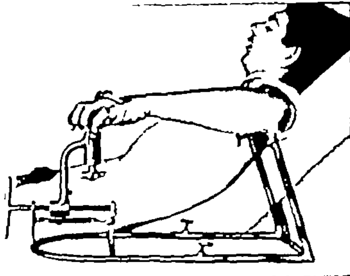


Fig. 1099 Fig. 1100

Fig. 1099 The forearm secured, as seen from above Ulnar abduction of hand. This position is usually required for reduction of fractures of the radius alone The strap holding the fingers crosses the knuckles thus allowing sufficient room for driving the nail into the radius above the wrist joint

Fig 1100 Same seen from the side The olecranon is freely accessible for nailing If necessary lateral traction straps can be used

tube is placed under the small table with the radiolucent wooden top, the other, opposite the radial side of the forearm (Fig 1098)

Reduction of fragments If both bones are broken and no displacement is present in the distal radio ulnar joint (Figs 1101 1102 1105 1106) the forearm is placed in supination in fractures of the proximal third in fractures of the middle and distal third the forearm is placed in mid position between pronation and supination, the wrist in mid position between flexion and extension and between radial and ulnar abduction, as in Figs 1098 and 1100 If the radius only is broken in the proximal third and a central subluxation exists in the distal radio-ulnar joint, as in Fig 1111 the forearm is placed in supination and the wrist in ulnar abduction

Likewise in isolated fractures of the middle and distal third of the radius (Fig 1117) the forearm must be placed in supination and the hand in ulnar abduction Mid-position between pronation and supination and ulnar abduction at the wrist is shown in Fig 1099 The muscle action which brings about the displacements is discussed on pages I/547, 548 and shown in Figs 405 E, I/1000, 1001

In fractures of the ulna alone with dislocation of the radius in the proximal radio-ulnar joint (Figs 1172–1179 and 1180 1181) the central dislocation of the entire radius is also reduced by longitudinal traction and ulnar abduction and the dislocation of the head of the radius by direct pressure (Figs 379 E I 862)

If angulations persist, they are corrected by lateral pressure Sometimes lateral displacement can be corrected only by strongly angulating (toggling) the fragments (Figs I/16–18) The reduction is checked by bi plane fluoroscopy One loop each is placed over the middle of the radius and of the ulna and connected to the wooden frame for the exertion of lateral traction during the operation, if necessary

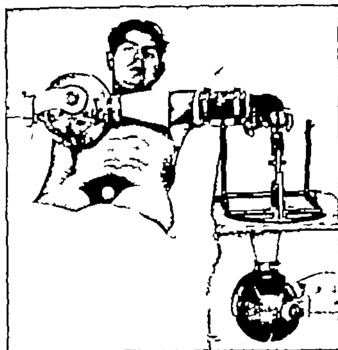


Fig 1098

Fig. 1098. The forearm is secured for medullary nailing by the traction apparatus (Fig. 98) The hand is placed midway between flexion and extension and midway between radial and ulnar abduction, the forearm midway between pronation and supination and the elbow at a right angle. With a ball-joint the wrist and forearm can be turned into any desired position as required for reduction and medullary nailing. The 2 X ray tubes are set up for fluoroscopy The top of the table is of wood and transmits X-rays.

Personnel An assistant is needed for the supervision of the patient (appearance and pulse) and for possible anesthesia a fluoroscopist, an instrument nurse and an X ray technician are also needed

Anesthesia Plexus anesthesia is best suited (see page I/101) Local anesthesia is not sufficient because the traction on the fingers is too painful

Protection against heat loss As in any other operation the patient must be well covered to prevent chilling

Securing the forearm in the reduction apparatus The patient reclines on his back in a semi sitting position The reduction apparatus (Figs 98 and 1098–1100) is placed upon a table with a wooden top alongside the operating table The apparatus is firmly fastened to the small table and this in turn is secured to the operating table so that it will always remain stationary A wooden frame similar to the one shown in Figs 527 and 803 is placed over it To this straps can be applied for traction in any desired direction This wooden frame is not yet shown in Figs 1098–1100 The upper arm is fastened with 2 straps to the 15 cm well-padded trough The hand is fastened by a strap across the knuckles of the 2nd to 5th fingers to the wooden block which is attached to a ball and-socket joint. The 3 wedges of cork fastened to the wooden block prevent the fingers from sliding off when the forearm is put under traction with a screw

Placing of X ray machines After the original X ray pictures, not sketches are displayed for convenience inspection and measuring during the operation one X ray



Figs 1105 1106 Fracture of both forearm bones in the middle third with complete lateral displacement and shortening of 2 cm., in a 14 year-old helper whose arm was caught in a press.

Figs. 1107 1108. Same as Figs 1105 and 1106 immediately after open medullary nailing of the radius, which was performed 6 weeks after injury because the fragments re-displaced repeatedly in an unpadded cast This was followed by a plaster cast from the knuckles to the shoulder for 6 weeks.

Figs 1109 1110 Same as Figs 1107 and 1108 immediately after removal of the medullary nail and 5 months after nailing Bony union of the radius in ideal position The ulna shows a dorsal angulation of 15° Rotation of the forearm restricted by one third. All other joints actively free.

ulna only the skin over the olecranon is sterilized in isolated fractures of the radius only the skin over the wrist joint is sterilized, in fractures of both bones both these places are sterilized and draped with a sterile split sheet

Incision over ulna In fractures of the ulna a 1–2 cm skin incision is made over the tip of the olecranon

Piercing the bone with the awl and insertion of the guide wire The olecranon is pierced superficially with the awl under fluoroscopic control 5–7 mm proximal from its extensor surface During this procedure the X ray tubes must be focused over the elbow joint Care must be exercised not to enter too close to the joint so as not to damage the cartilage Under fluoroscopic control, a steel wire of 1 5 mm thickness is then worked into the medullary cavity by means of a handle (Figs 81, 82) and pushed past the fracture line into the distal fragment

If the medullary canal is very narrow the nail is inserted without the guide wire

Driving the nail If the guide wire is in good position the medullary nail which has previously been accurately measured is driven in over it under the control of short fluoroscopic thrusts The fluoroscopic check up must be particularly careful as the nail approaches the fracture to make sure that it does not proceed alongside



Fig 1101 Fig 1102 Fig. 1103 Fig. 1104

September 26 1942 September 26, 1942

Figs. 1101 1102 Transverse fracture of both forearm bones between the middle and distal third with overlapping and shortening of 1 cm., in a 46-year-old stage hand.

Figs. 1103 1104 Same as Figs. 1101 and 1102 after closed medullary nailing. Both bones show perfect position in both planes Remained without plaster cast because the nails were sufficiently long and thick. Courtesy of Maatz ("Der Chirurg," No. 9 1943)

Fluoroscopy Reduction is accomplished under continuous fluoroscopic control with short exposures of 1–2 seconds

Irradiation damage must be avoided by following the rules given on page 37 (use of lead gloves lead aprons and momentary fluoroscopic thrusts of 1–2 seconds)

X ray pictures If fluoroscopy seems to show good reduction X ray pictures (in two planes) are taken including the wrist and elbow joints.

Rapid development To prevent undue waiting a rapid developer is used (see page 35)

The operation must not be started until the fragments and the joints are well reduced because **accurate reduction of the fragments is indispensable for the smooth course of the operation and uneventful healing**

Sterile draping of the operative field The surgeon does not scrub until the fragments have been well reduced and firmly anchored In isolated fractures of the



Fig. 1117 Fig. 1118
September 25 1942

Fig. 1119 Fig. 1120
November 20 1942

Fig. 1121 Fig. 1122
March 8 1943



Fig. 1123 Fig. 1124
June 5 1943

Fig. 1125 Fig. 1126
November 11 1943

Figs. 1123 1124 Same as Figs 1121 and 1122 after 3 months, and 9 months after the accident. The slight callus has disappeared and there is a gap between the fragments.

Figs. 1125 1126 Same as Figs 1123 and 1124 after extraction of the nail and 14 months after the accident. Fully developed pseudarthrosis. If no nail had been used, bony union would probably have taken place in 3–4 months as in Figs 411–414 E I/1002–1009 and I/1028–1031 and the central dislocation at the distal radio-ulnar joint would have been much less pronounced

of a handle (Figs 81 82) into the medullary cavity past the fracture site, under adequate fluoroscopic control

Driving the nail When the guide wire is in good position, the nail is driven in under the control of momentary fluoroscopic exposures The head of the nail must



Fig 1111 Fig 1112 Fig 1113 Fig. 1114 Fig 1115 Fig 1116
August 21 1942 August 26, 1942 March 20, 1943

Figs. 1111 1112. Closed transverse fracture of the radius in the proximal third with lateral displacement of the distal fragment in a 63-year-old helper who was struck on the forearm by a piece of iron.

Figs. 1113 1114. Same as Figs 1111 and 1112 after open nailing with a nail 16 cm. long and 3 mm. thick. Good position Plaster cast, including the upper arm, for 8 weeks.

Figs. 1115 1116 Same as Figs 1111–1114 after removal of the nail and 7 months after operation. Bony union in good position. Rotation one half restricted, all other joints actively free. The same result could have been attained in a simpler and less dangerous way with a plaster cast, without open nailing

Figs. 1117 1118. *Compound* fracture of the radius between middle and distal third with avulsion of the ulnar styloid process. *The distal fragment of the radius is displaced towards the ulna and anteriorly by the* full width of the shaft, angulated 15° with a shortening of 1 5 cm. Dislocation at the radio-ulnar joint.

Figs. 1119 1120 Same as Figs 1117 and 1118, two months after thorough excision and open medullary nailing with a nail of 12 cm. length and 3 mm. thickness. Excellent position of the fragments immediately after removal of the plaster cast. Decalcification at the wrist joint. Wide fracture line. No callus formation.

Figs. 1121 1122. Same as Figs 1119 and 1120 after 4 months, and 6 months after the operation Fracture apparently healed with good alignment and a shortening of 1 cm. Therefore central dislocation at the distal radio-ulnar joint.

the distal fragment, instead of into it The nail selected must not be too thick so that it can be readily retracted

Skin incision over the radius and piercing with the awl In isolated fractures of the radius a 2–3 cm longitudinal incision is made over the dorsal surface of the radius 2 cm proximal from the wrist The bone is approached between the extensor tendons. The soft tissues are spread by the self retaining retractor and the bone is pierced with the awl

One may also enter over the styloid process of the radius (Fig 1103)

Insertion of the guide wire The guide wire 1.5 mm thick is inserted by means

pseudarthrosis may ensue Extraction is usually easily accomplished and can be carried out as a rule on the ambulant patient under local anesthesia If the nail of the radius had not been bent up and therefore possibly worked its way into the bone, extraction may be very difficult

Causes of Failure of Closed Medullary Nailing in Forearm Fractures

1. **Operating under shock** **This may cause death** **Medullary nailing** is no emergency procedure
2. Operating in the presence of swelling or fever Medullary nailing is no emergency procedure
3. Operating in the presence of deep skin abrasions or unhealed wounds on the injured arm or in other parts of the body i e before 2–3 weeks have elapsed unless the operation could be performed in the first few hours Medullary nailing is no emergency procedure
4. Operating in fractures of both forearm bones which are less than 6 cm removed from the wrist and in isolated fractures of the radius which are less than 10 cm removed from the wrist joint
5. Operating without the required instruments (ample variety of nails, extractors etc)
6. Operating without reduction apparatus
7. Operating with one, instead of two X ray machines
8. Neglecting to administer local anesthesia for the X ray pictures because these can then not be focused satisfactorily
9. Neglecting to determine accurately the length and width of the medullary canal.
10. Neglecting to protect against heat loss
11. Neglecting to fasten the small wooden table to the operating table
12. Failure to reduce the fragments and the dislocations accurately
13. Neglecting to check the position after reduction by X ray pictures
14. Neglecting to insert the guide wire
15. Neglecting to use the fluoroscope while inserting the guide wire
16. Fluoroscoping without lead gloves and lead apron.
17. Failure to bend the nail for the radius upwards
18. Failure to check carefully by fluoroscopy the progress of the nail after it reaches the fracture site
19. Failure to take X ray pictures after the driving of the nails
20. Failure to impact the fragments
21. Neglecting to exercise actively the fingers and the shoulder through the full range from the first day on
22. Premature exercises of wrist and elbow joints and of pro-supination i e before one week
23. Exercises on the horizontal and vertical pulley, this may cause separation of the fragments
24. Use of vigorous massage and forcible passive motion This may lead to delayed callus formation and to pseudarthrosis

be bent (Fig 1169) so that it will not bury itself in the bone, otherwise, it is difficult to remove it Maatz has also pointed this out

Nailing of both bones If both bones are broken they are both nailed in the manner described above Sometimes nailing of the ulna alone is sufficient. Nailing of both bones is very difficult

Skin suture and pressure bandage After the nails have been driven, the wounds are closed with 1 or 2 skin sutures. A light pressure bandage is applied to prevent hematoma

X ray pictures Bi-plane X ray pictures are then taken to determine the position of the fragments and the position of the nail

Impaction of the fragments If these pictures show a hiatus between the fragments, the forearm must be compressed longitudinally between the hand and the elbow

Supplementary external support If both nails were of the proper length and thickness no plaster cast or splint is needed post-operatively Otherwise a cast is applied to the arm in mid-position of all joints as shown in Figs 392–394 E, I 913–915

Exercises The fingers and the shoulder joint are exercised actively through the full range from the first day on Motions in the wrist and elbow joints particularly rotation must not be started until after one week Motion must remain within the limits of pain Exercises on the horizontal or vertical pulley must be omitted since they might cause distraction of the fragments

Use of a sling During walking the arm must be carried in a sling for 3–4 weeks. Since carrying of an injured arm in a sling has frequently caused marked stiffening especially of the shoulder many call the sling the "burial sheet of the arm and want it eliminated. In my opinion, any injured arm must be carried in a sling as long as it is painful It is however necessary to exercise all joints in the manner described above Neither the sling nor the patient is responsible for the stiffening but the one who fails to see to it that the proper exercises are carried out daily according to a plan

Vigorous massage and forcible passive motion The old dictum that these two methods are most injurious in all fresh as well as in most old injuries (see page I/37) holds true for medullary nailing as well It may lead to pseudarthrosis. The rule

Exercises must never cause pain

(see page I 31) applies equally after medullary nailing

Subsequent observation and nailing record After discharge from the hospital the patient must return at least once a week for a check up If he does not live too far away it is advisable that he return daily or every other day for group exercises. After return to work he must report every 2 months for an X ray check up A careful record file of nailed cases will prevent neglect or unintentional oversight of the follow up (see page 54)

Extraction of the nail The nails must be left in situ until the fractures show bony consolidation i.e at least 4–6 months. If they are removed too soon bowing or

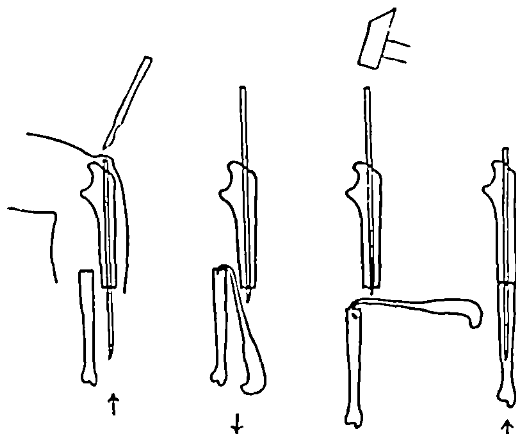


Fig. 1126 a. The fracture of the ulna is exposed. The medullary nail is inserted through the fracture surface into the proximal fragment and bulges the skin over the olecranon where the skin is incised.
Fig 1126 b. Correction of the shortening by traction with a single-pronged bone-hook.
Fig 1126 c Correction of lateral displacement by means of a hook.
Fig 1126 d. After reduction the nail is driven into the distal fragment. The fragments are impacted.

Contra indications with regard to the patient If the general condition is poor (rapid weak pulse pale appearance cold sweat) medullary nailing must under no circumstances be performed **If the patient is in profound shock as is frequently the case in multiple injuries, medullary nailing must positively be omitted, or the outcome may be fatal**

If the general condition is poor a simple plaster cast (Figs 392–394 E I 913–915) is applied and no transfixion cast (Figs 395–400 E I 936–941)

Contra indications with regard to the soft tissues and the bone Large wounds are no absolute contra indication Fractures less than 6–10 cm from the wrist must not be nailed because the nail does not provide sufficient stability In particular fragments extensively denuded of periosteum (Figs 1136 1137 and I 149 150) must be excluded from nailing because the stumps will be sequestrated if a medullary nail or a wire occupies the medullary cavity (Figs 1140 1141 1142)

Detailed examination of the patient While the patient is kept warm the extent and depth of the injury are accurately determined The fingers are checked for circulation and for a pale or bluish discoloration Motion of the fingers the sensation and reflexes are checked as well as the pulse at the wrist It must be kept in mind that in shocked or exsanguinated patients the pulse is frequently not pal

25 Neglecting to follow up until the fractures are firm and the nail removed.
26 Neglecting to record nailed cases in a special file
27 Premature extraction of the nail
28 Neglecting to take X ray pictures at the conclusion of the treatment

Open Medullary Nailing of Fresh Closed Forearm Fractures

Like Küntscher and Maatz my associates proceeded very cautiously with the nailing of forearm fractures and usually exposed only one of the two broken bones operatively and nailed it In the erroneous assumption that it is sufficient to grasp but 4–6 cm of each fragment only short nails, suitably bent, were used (Figs. 462–467 1119–1122, 1129–1132, 1154–1157) A hole was made in the shaft of the bone with a round burr either in the operative wound or through an additional incision. Even on the ulna the logical entry through the olecranon was intentionally avoided (Figs. 1129–1132) for fear as I heard later, of an olecranon bursitis which sometimes leads to severe epifascial purulent cellulitis This however, does not follow aseptic operations, but soiled accidental wounds.

Since usually only one bone was nailed and because only short nails were used, a plaster cast in mid position of all joints was applied post-operatively in all cases (Figs 392–394 E I/913–915)

Figures 462–467 show that it is not sufficient to nail the radius only If the operation is limited to one bone it should be the ulna. Because of its subcutaneous location its exposure is less dangerous In contrast to the other bones we do perform open nailing even in fresh closed fractures of the ulna The technique is described on page 349 If a third wedge fragment is present, as in Figs 460 or 1180–1185 a wire loop may be added

Rejection of Open Medullary Nailing in Fresh Compound Forearm Fractures

In every compound forearm fracture there is danger of infection because the fragments were exposed by the trauma. The question is whether this danger is increased or decreased by medullary nailing Until now I have rejected the usual osteosynthesis in fresh compound fractures of the forearm because its use requires broad exposure of the fragments and because it does not provide sufficient stability These two disadvantages are overcome by the use of Küntscher s nail and therefore I formerly permitted its use in selected cases. But I have abandoned it again because in case of infection the entire medullary canal becomes involved whereas without the nail the infection remains localized to the fracture site Without nailing I never saw such large sequestra as shown in Figs 1140–1143 In markedly displaced fractures I now sometimes use a wire suture

If open nailing is contemplated nevertheless the following must be observed

General requirements with regard to the patient Medullary nailing may be performed only if the patient is in good general condition

Local requirements with regard to the bone The fracture must be at least 6–10 cm distant from the wrist and the fragments must be covered with periosteum



Fig 1131 April 28 1942 | Fig 1132 August 27 1942 | Fig 1133 | Fig 1134 February 18 1943

Fig 1131 Same as Fig 1130 immediately after removal of the first nail and insertion of a new nail 4 mm thick which protrudes 2 mm. beyond the olecranon Thereupon plaster cast including the upper arm for 4 weeks

Fig 1132. Same as Fig 1131 after another 4 weeks and 1 8 months after the accident. Increased callus formation

Figs. 1133 1134 Same as Figs 1127 and 1128 fourteen months after the accident and 5 months after removal of the nail The fracture shows bony union with an angulation of 15 all motions actively free If merely a plaster cast without nailing had been applied following excision healing would have been obtained in a much simpler and less dangerous way and in a shorter time as well since the fragments could have more readily moved together

There are cases of arm injuries in which the bones are broken and the skin and muscles extensively torn so that they are connected only by intact blood vessels and nerve bundles These can be saved as shown in Figs I/140-148 and I/149-157

Time of nailing Nailing must, as a rule be carried out only within the first 6–8 hours, before any inflammation develops. Late operation may be followed by inflammation of the medullary canal and massive sequestration

Instruments and apparatus For open nailing the equipment for closed nailing as listed on pages 22–26 is needed as well as the instruments shown in Figs 85–91 A reduction apparatus is not required but one X ray machine is necessary

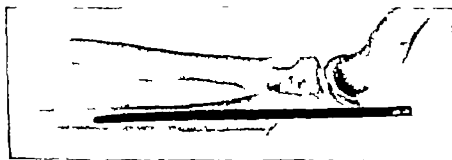


Fig 1135

Fig 1135 Closed fracture of the forearm at the upper end without displacement. The nail has been introduced through the olecranon This provides good immobilization and prevents such angulation as in Figs 1129–1134 Courtesy of A. W Fischer and Maatz (Arch f Klin Chir 203 No. 4 1943)

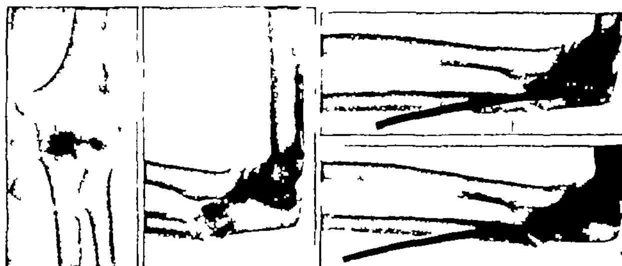


Fig 1127 Fig 1128 Fig 1129 Fig 1130
December 5 1941 January 5 1942 April 27 1942

Figs. 1127 1128. *Compound* fracture of the left ulna in the proximal third, with a third fragment 11 x 13 mm. Distal fragment angulated forward by 15° Suffered by a 40-year-old printer whose arm was caught in a press. *The wounds were debrided immediately The ulna was opened with a round burr Insertion of* a medullary nail 13 cm. long and 3 mm. thick, application of a plaster cast which was immediately split and fenestrated.

Fig 1129 Same as Fig 1128 after 4 weeks, immediately after removal of the cast. Wounds healed without disturbances. The fracture is gaping Resumed work 4 weeks later

Fig 1130 Same as Fig 1129 after 4 months. The fracture line has become much narrower and is partly bridged by bone. The nail migrated outwards and pierced the skin.

pable Its absence on the injured side only, is an indication that the main artery is torn or blocked by a blood clot or compressed by a fragment

First local anesthesia After this examination which should be brief, the fracture is anesthetized by the injection of 0 5 per cent of novocaine solution between the fragments by entering through healthy skin and not through the soiled wound With the disappearance of pain the general condition usually improves and the pulse becomes stronger and slower (see case history on page I 109) Also brachial plexus anesthesia may be used

Infusion and transfusion If the patient does not recover in spite of warming, hot drinks and local anesthesia he is given an infusion of 500 cc of isotonic solution of blood serum salts and preparations are made for blood transfusion

X ray pictures If the patient responds to these measures X ray pictures are taken in both planes to determine the type and extent of the bone injury It is best to use a film 40 cm long for the survey of the wrist and elbow joints

Amputation of the injured arm If the arm remains without sensation cool and pale, and if the blood does not return after pressure upon the fingernails even though the patient has recovered the arm must be amputated in time—if possible within the first 6–8 hours—to permit closure of the stump Patients sometimes refuse amputation because they can still move the fingers. *If the nerves and tendons are* intact the fingers can be moved even if both main arteries are severed and the arm not viable.

Incision over ulna and insertion of nail If the ulna alone is broken the nail is driven from the fracture site into the proximal fragment until it perforates the olecranon and bulges the skin, which is then incised The nail is driven in further until it protrudes only 0 5 1 cm from the fracture stump Both fragments are then placed in apposition and held firm with a Lambotte clamp (Fig 85) while the nail is driven into the distal fragment

Incision over the radius and piercing with the awl If only the radius is broken a 2-3 cm longitudinal incision is made on the dorsal surface 1-2 cm proximal to the wrist The bone is approached between the extensor tendons and pierced with the awl One may also enter through the styloid process

Driving the nail The nail which is slightly bent at the end is then driven in until it appears in the fracture The fragments are then held together with a Lambotte clamp and the nail is driven further

Nailing of both bones If both bones are broken, they are both nailed in the manner described above

Impaction of the fragments If the fragments are not in accurate apposition they are carefully impacted

X ray pictures After the nails have been driven, bi plane X ray pictures are taken and developed with a rapid developer (see page 35)

Insertion of drains If the fragments are in good position drains are inserted into both fractures these drains are carried out through healthy skin and held with a suture

Wound closure If no more than 6-8 hours have elapsed the skin and the skin only is closed with sutures no ligatures (see page I 113) or sutures are buried Only in the case of severed nerves is an exception made to this rule

Pressure bandage The wounds and nailing sites are covered with a light pressure bandage to prevent hematoma

Plaster cast For immobilization of the soft tissue wounds a plaster cast is applied from the knuckles to the shoulder (Figs 392–394 E I/913–915) this must be split and fenestrated immediately

Removal of drains and open wound treatment After 24–36 hours the pressure bandage and the drains are removed and the wounds remain uncovered The drain openings are covered with a small dressing If fever redness and pain appear, the sutures must be removed

Exercises The fingers and shoulder are not exercised for an entire week

Removal of plaster cast If no wound inflammation sets in and if the nails were sufficiently long and thick as in Figs 1103 1104 the cast may be removed after 3 weeks

X ray pictures After removal of the cast bi plane X ray pictures must be taken immediately and repeated every 2 weeks

Vigorous massage and forcible passive movements must be guarded against particularly in compound fractures of the forearm because they may lead to late infection or pseudarthrosis (see page I 37)

Determination of the length and width of the medullary canal The length of the bone is determined from the well arm This is simple and reliable because the ends of the bone can be readily palpated with the elbow at a right angle The nail should usually be 3–6 in shorter than the broken bone Until recently the nails that were used were usually too short (Figs 462–467 1119–1122 1129, 1132)

The width of the medullary canal is measured on the X ray pictures. In adults the narrowest area varies from 2–5 mm towards the ends it expands slightly (Figs 34–42 and 45–53)

Personnel One assistant is needed for the wound excision, another for the observation of the patient (appearance pulse and possible general anesthesia) an instrument nurse and an X ray technician are likewise needed

Second local anesthesia Local anesthesia serves best for wound excision A solution of 0.5% novocaine is infiltrated into the torn soft tissues and into the nailing sites. For the driving of the nail a short general analgesia is frequently required. If brachial plexus anesthesia was used no further local anesthesia is necessary

Protection against heat loss As in any operation the patient must be protected against heat loss

Wound excision Within the first 6–8 hours the wounds are accurately excised according to the rules given on pages I 106–130, where the procedure as to the skin fascia muscles tendons blood vessels nerves and bone is detailed

The wounds frequently must be extended by adequate longitudinal incisions in both directions to afford access for the removal of all torn and soiled tissues The skin must never be incised transversely not even in transverse wounds because the retracted muscle stumps will not then be found Especially the stumps which have retracted toward the wrist are hazardous Sometimes it is advisable to leave a *bridge of skin intact and to make a new longitudinal incision towards the wrist joint* All devitalized tissue must be removed while the blood vessels and nerves are carefully preserved and only the soiled adventitious tissue is removed from them. Soiled bone is removed with a chisel or rongeur Fragments connected with the periosteum are not removed To overcome large skin defects, it is sometimes advisable to shorten the bones slightly For thorough debridement one hour or more may be required

Blood transfusion If the pulse and general appearance have not improved in the meantime a blood transfusion of 400–500 cc. is administered.

Application of a simple plaster cast or of a double wire transfixion cast If the general condition of the patient does not improve or if the fracture is not suited for medullary nailing because of avulsion of the periosteum (Figs 1136 1137 and I/149 150), a simple plaster cast is applied (Figs 392–394 E I/913–915) or a double wire transfixion cast (Figs 395–400 E I/936–941 and I/942–953) if there was marked displacement or comminution

If the radius alone is broken a wire through the distal end of the radius and ulna is sufficient. As soon as swelling and pain appear the cast must be split

Open medullary nailing If the general and local conditions are satisfactory, medullary nailing may be performed



Fig 1140 Fig 1141 Fig 1142 Fig 1143 Fig 1144 Fig 1145

July 27 1942 September 1942 March 11 1943

Figs. 1140 1141 Same as Figs 1136–1139 after 3 months Those parts of the 2 bones which had protruded through the wound and were soiled and chilled sequestrated Without wire these pieces would probably have been smaller because the bone marrow would not have been destroyed A simple wire suture of the radius would have served the purpose better and could have been applied much more quickly

Figs 1142, 1143. Same as Figs 1136–1139 after 4½ months The necrotic piece of the ulna is removed At the radius periosteal callus has formed which connects the two fragments.

Figs 1144 1145 Same as Figs *1136–1139 after 10½ months* Radial *fragments united by narrow callus* bridge Angulation 20 Distal fragment of ulna united to the radius Ulnar defect pseudarthrosis.



Fig 1146 Fig 1147 Fig 1148 Fig 1149 Fig 1150 Fig 1151

July 14 1943 October 18, 1943 June 19 1944

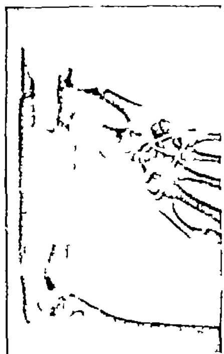


Fig 1136



Fig 1137

April 27 1942



Fig. 1138 Fig. 1139

April 27 1942

Figs. 1136, 1137 *Compound* fracture of the left forearm in the distal third. The proximal fragment of the radius protrudes 5 cm. and that of the ulna 7 cm. through the wound. Both are badly soiled. The pulse can be palpated in the radial artery but not in the ulnar artery Good circulation in the fingers which can be moved actively Suffered by a 46-year-old mechanic whose arm was caught in a machine.

Figs. 1138, 1139 Same as Figs 1136 and 1137 after thorough debridement of the wound and of the fragments with a rongeur and after medullary nailing. Since the medullary canals were surprisingly narrow only a 1.5 mm. wire could be used for the ulna and a 1 mm. wire for the radius. They were introduced through holes drilled into the proximal fragments. A drain is visible. Good position of the fragments. After an initially uneventful course, light fever and suppuration occurred after 8 days. Afebrile from the 11th day on.

Figs 1146, 1147 Same as Figs 1144 and 1145 after 4 months, and 15 months after injury The fragments of the radius are united by a fairly strong eburnated bridge of bone. Since this seemed to be strong enough, no new plaster cast was applied. Angulation 25°

Figs. 1148, 1149 Same as Figs 1146 and 1147 after 3 months and 2 months after the application of a new cast. The sclerosed, and therefore inelastic, bridge of callus broke soon after the removal of the cast. The fracture line now gives the appearance of a pseudarthrosis. Angulation 35°

Figs. 1150 1151 Same as Figs 1148 and 1149 after 8 months and 26 months after the injury The pseudarthrosis on the radius is bridged by bone and has become stronger At the distal end of the ulna a large cavity can be seen, the remnant of a bone abscess which formed 15 months after removal of the wire in the region where the tip had been Defect pseudarthrosis of ulna unchanged. Bridge callus between radius and distal fragment of the ulna. Sinus closed for several days. The fingers can be extended to 165° and flexed to within 1 cm. of the palm. The thumb can be flexed down to the metacarpo-phalangeal joint of the ring finger Grip comparatively strong If no medullary wires had been used in this case, no large massive sequestra would have separated. If both wires had been removed in time the fragments could have moved together and bony union might possibly have ensued. This would have prevented the marked angulation. Without medullary wires, no late abscess would have formed at the distal end of the radius. If the previous methods had been used, as in Figs I/149–157 the same result would probably have been obtained in 5 months, whereas the treatment with wires consumed 26 months.



Fig. 1140 Fig. 1141 — July 2, 1942
Fig. 1142 Fig. 1143 — September [illegible] 1942
Fig. 1144 Fig. 1145 — March 11, 1943

Figs. 1140, 1141. Same as Figs. 1136–1139 after 3 months. Those parts of the 2 bones which had protruded through the wound and were soiled and chilled sequestrated. Without wire these pieces would probably have been smaller because the bone marrow would not have been destroyed. A simple wire suture of the radius would have served the purpose better and could have been applied much more quickly.

Figs. 1142, 1143. Same as Figs. 1136–1139 after 4½ months. The necrotic piece of the ulna is removed. At the radius periosteal callus has formed which connects the two fragments.

Figs. 1144, 1145. Same as Figs. 1136–1139 after 10½ months. Radial fragments united by narrow callus bridge. Angulation 20°. Distal fragment of ulna united to the radius. Ulnar defect pseudarthrosis.



Fig. 1146 Fig. 1147 — July 14, 1943
Fig. 1148 Fig. 1149 — October 18, 1943
Fig. 1150 Fig. 1151 — June 19, 1944



Fig 1152 Fig 1153 Fig 1154 Fig 1155 Fig. 1156 Fig 1157

February 26 1942 February 27 1942 February 14, 1943

Figs. 1152, 1153 A 4-months-old fracture of both forearm bones above the middle. Bony consolidation of the radial fracture On the ulna the fracture line is still visible Volar angulation of 20° ulnar angulation of 25° Rotation about one-half restricted

Figs. 1154 1155 Same as Figs 1152 and 1153 after operative exposure and severance of the radius and after bloodless fracturing of the ulna. After drilling an opening into the distal fragment with a round burr a nail 10 cm. long and 4 mm. thick was driven in.

Figs. 1156 1157 Same as Figs 1152–1155 after one year Both fragments show bony consolidation. The ulna shows a volar angulation of 10° All joints free.

Again the rule holds true (see page I 31) **Exercises must never cause pain**

Removal of sutures If no wound disturbances occur the sutures should not be removed before 3 weeks

Subsequent supervision

use of a special record file and

the extraction of the nail are carried out in the same manner as in closed forearm fractures (see page 342)

Complications Next to the loss of an arm the most serious complication is infection and the separation of large sequestra (Figs 1136–1145) To prevent such extensive loss of bone in cases with large wounds with wide exposure of bones denuded of periosteum no nails or wires must be introduced into the medullary cavity because they destroy the bone marrow The bone then obtains no nutrition either from outside or inside and therefore sequestrates (Figs 1140–1143) In such cases it is better to use a simple wire suture

Results We have to date nailed 6 compound forearm fractures One case had to be amputated the next day because gangrene set in The arm was injured by a



Fig 1158 Fig 1159 Fig 1160 Fig 1161

October 29 191 January 18 1943

Figs. 1158, 1159 A 15-months-old mal united fracture of the left radius and pseudarthrosis of the ulnar styloid process. The distal fragment is displaced radially Radial angulation of 30 and dorsal angulation of 40° Central dislocation of the ulna at the distal radio-ulnar joint Fingertip-palm distance 4 cm. Rotation limited to one half After exposure and open osteotomy of the radius, a medullary nail 9 cm. long and 3 mm. thick was inserted The wedge which had been removed from the volar surface was inserted into the dorsal surface

Figs. 1160, 1161 Same as Figs 1158 and 1159 after 2½ months. The lateral displacement of the distal fragment towards the radial side has been corrected. The angulation still persists. In the lateral view the dorsal angulation has been reduced from 40° to 20 Beginning callus formation



Fig 1162 Fig 1163 Fig 1164 Fig 1165

June 9 1943 June 10 1943

Figs. 1162 1163 Same as Figs 1158–1161 after 7 months. Bony consolidation of the fracture

Figs. 1164 1165 Same as Figs 1162 and 1163 after extraction of the nail. Normal motion of fingers forearm rotation one third limited

transverse saw cut which had severed both arteries These were sutured but even with a medullary nail such injuries cannot be repaired In one case large massive sequestra and a late abscess formed at the lower end of the radius (Figs 1136–1151)

This case was not suited for medullary nailing either for the reasons given above In the case of Figs 1117–1126, a pseudarthrosis developed although such fractures usually heal firmly without nailing (Figs 407–414 E I/1002–1031) In only three cases did bony union occur without wound disturbances although the nails used were too short (Figs. 1127–1134)

Rejection of open medullary nailing of fresh compound forearm fractures I have prohibited this procedure within my jurisdiction because I saw no advantages and only great disadvantages in it

Under the protection of *penicillin* infections might possibly be avoided

Open Medullary Nailing of Fresh Gunshot Fractures of the Forearm

In contrast to gunshot fractures of the femur, it is comparatively easy to immobilize gunshot fractures of the forearm with a plaster cast If a marked tendency to redisplacement persists, as is usually the case in gunshot fractures of the radius alone (Figs 395–400 E, I/936–941), good position can be maintained by a wire transfixion cast. For this reason there is no urgent need for nailing such cases I am inclined to advise strongly against it in view of the unfavorable experiences met with on fresh compound forearm fractures

Open Medullary Nailing of Infected Gunshot Fractures of the Forearm

Open medullary nailing should be rejected for infected gunshot fractures of the forearm because massive sequestra similar to Figs 1139–1142, will form if the nailing is done in the presence of suppuration

Open Medullary Nailing of Old Forearm Fractures

Angulations of the forearm bones interfere with rotation and should therefore be corrected if the local and general conditions permit Küntscher's medullary nailing has the advantages that with proper selection of the cases and with correct technique displacement will not recur and that the joints can as a rule be exercised early, i.e after wound healing

The procedure is never urgent and must therefore be performed only if the general condition is good and the skin normal. If the skin shows any pathologic changes one must wait until it has been normal for at least 2 months

Indications for medullary nailing of old forearm fractures The main indications are delayed union marked angulations narrowing of the interosseous space and subluxation at the distal radio-ulnar joint

Contra indications to medullary nailing of old forearm fractures

1 Poor general condition All internal organs especially of circulation must be in a healthy condition
2 Age over 40 years Only in exceptional cases should older people be operated upon.
3 Local inflammatory processes in the bone Sinuses must have been closed for at least 6 months



Fig. 1166 Fig. 1167 Fig. 1168 Fig. 1169 Fig. 1170 Fig. 1171

August 7, 1943 August 18, 1943 April 17, 1944

Figs. 1166, 1167 A 4-year-old pseudarthrosis of both forearm bones on the right side in the upper third. In the A P view the distal fragments are rotated 90° against the proximal fragments. Ulnar angulation of 35°. Central dislocation of the radius by 12 mm. at the distal radio-ulnar joint. Suffered by a 46-year-old sawmill superintendent who was struck on the forearm by a guard-rail, causing a *compound* fracture. Treated *elsewhere*.

Figs. 1168, 1169 Same as Figs. 1166 and 1167 after transverse freshening of the fragments after medullary nailing of both bones, and wire suture of the ulna. A drain is inserted over the ulna. Angulation corrected. The central dislocation of the radius at the distal radio-ulnar joint reduced to 4 mm.

Figs. 1170, 1171 Same as Figs. 1168 and 1169 after 8 months. Slight secretion of a few drops of pus from several suture openings over the ulna without rise of temperature. Wound over the radius remained reactionless. Since no callus formed and the fracture line widened, the nails and the wire were removed after 4 months. The condition is now worse than before the operation. If the fragments had been freshened and massive tibial grafts implanted, bony union would probably have ensued in 3 months, as in Figs. I/1059–1062.

4. Marked decalcification of the bones with simultaneous circulatory disturbances. Dystrophic limbs are particularly prone to post-operative infection.
5. Skin pathology (inflammations, extensive adherent scars).
6. Marked impairment of the bones and joints.

The length and width of the medullary canal are determined in the same manner as in fresh closed forearm fractures (see page 335).

Anesthesia. Brachial plexus anesthesia is best suited (see page I/101).

Exposure of the fragments. The ulna is approached from the dorsal surface, the radius in the distal and middle third from the radial side. For the proximal third of the radius either a volar or dorsal approach is chosen. The radial nerve must then be carefully protected.

Procedure with pus pockets. If a cavity filled with granulations or pus is met



Fig 1172 Fig 1173 Fig 1174 Fig 1175

January 12 1942 June 6, 1942

Figs. 1172, 1173 A 2 year-old pseudarthrosis of the ulna with dislocation of the radius (Monteggia) On the ulna a dorsal and ulnar angulation of 20° each. Over the head of the radius a cup-shaped ossification of the capsular ligaments 5 x 20 mm. Suffered by a 46-year-old workman who was knocked down by an automobile. Treated *elsewhere*

Figs. 1174, 1175 Same as Figs 1172 and 1173 5 months after exposure of the ulna and insertion of a medullary nail 11 cm. long and 3 mm. thick The nail grasped only the cortex of the distal fragment and then perforated it. The angulations are improved. The pseudarthrosis persists.

Figs 1176 1177 Same as Figs 1174 and 1175 after 9 months, and 14 months after medullary nailing. The nail is broken. The angulation is the same as before the operation.

Figs. 1178, 1179 Same as Figs 1176 and 1177 4 months after removal of the broken nail, after freshening of the fragments and insertion of a new nail 15 cm long and 4 mm. thick, which in contrast to the first nail, is now located in the medullary canal of the distal fragment. The fragments are united by a longitudinal wire suture and are in good apposition but show no bony union. Probably this nail, too broke later

Fig. 1180 A 12 weeks-old leverage fracture of the ulna with 5 cm. wedge fragment on dorsum and volar dislocation of the head of the radius (Monteggia) Shortening and 15° dorsal angulation of the ulna. Considerable decalcification Suffered by a 30-year-old man in an airplane accident. Treated *elsewhere*.

Fig 1181 Same as Fig 1180 after wire traction to the radius with 4–5 Kg for 2 weeks. The volar dislocation of the head of the radius persists, but the central dislocation is corrected. The head of the radius is 20 mm removed from the humerus. The ulna is straightened and the fragments are distracted

Figs. 1182, 1183 Same as Fig 1181 after open reduction of the radius, and after exposure of the ulna, medullary nailing, and supplementary wiring

Figs. 1184 1185 Same as Figs 1182 and 1183 immediately after removal of the medullary nail and 6 months after the operation. The head of the radius is correctly reduced The ulna shows bony union. Although no ligamentary ossifications are evident in the region of the head of the radius, there is merely a suggestion of rotatory motion of the forearm. Elbow motion 65–110°



Fig. 1176 Fig. 1177 Fig. 1178 Fig. 1179

March 16, 1943 July 19 1943



Fig. 1180 Fig. 1181 Fig. 1182 Fig. 1183 Fig. 1184 Fig. 1185

Aug. 15 1943 August 29 1943 August 30 1943 February 23 1944



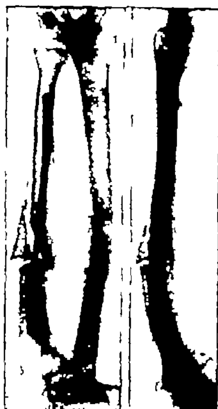


Fig 1186 Fig 1187 Fig 1188 Fig. 1189

October 3 1942 October 28 1942

Figs. 1186 1187 A 28-months-old pseudarthrosis of the left ulna with dislocation of the head of the radius toward the volar and radial side (Monteggia) A wedge fragment 15 x 50 mm. broke off the ulna which shows the typical angulations, 35° dorsal and 30° ulnar No ligamentary ossifications are noticeable around the head of the radius. In a 28-year-old man who fell from a motorcycle.

Figs 1188 1189 Same as Figs 1186 and 1187 after resection of the head of the radius, done *elsewhere*, and after medullary nailing of the ulna. An ulnar angulation of 20° persists because the nail is too thin and too short Relying upon the callus-stimulating effect of the nail, the fragments were not freshened.

Figs. 1190 1191 Same as Figs 1188 and 1189 after 7 months. The pseudarthrosis persists unchanged. The original angulations recurred The tip of the nail has perforated the proximal fragment on the radial side. Periosteal appositions have formed in this region

Figs. 1192 1193 Same as Figs 1190 and 1191 6 months after the first nail was extracted *elsewhere*, after removal of an additional piece from the proximal end of the radius, and removal of the wedge fragment of the ulna, after freshening of the fragments and introduction of a new longer and thicker medullary nail, and after uniting both bones with a wire suture. The nail, which was originally straight, has bent. No callus formation visible.

Figs. 1194, 1195 Same as Figs 1192 and 1193 after 4 months, and 10 months after the second operation. The nail broke as well as the wire. The fracture line is wider

Figs. 1196, 1197 Same as Figs 1194–1195 after removal of the broken nail and the broken wire loop. One year after the second, and one and a half years after the first operation, and 4 years after the accident, the forearm is 6 cm. shorter There is a defect pseudarthrosis of the ulna and loss of the proximal end of the radius. Marked decalcification. The forearm is flail and the arm is powerless. Before the operation the function of the arm was comparatively good. In March, 1945 a 10 cm. osteo-periosteal graft was implanted into the ulna. It took well and the function of the arm was again improved.



Fig. 1190 Fig. 1191 Fig. 1192 Fig. 1193

May 24 1943 November 20 1943

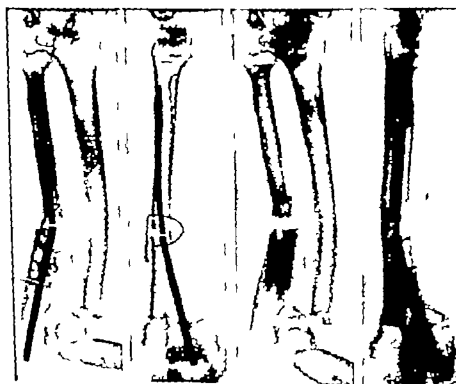


Fig. 1194 Fig. 1195 Fig. 1196 Fig. 1197

March 17 1944 May 6 1944



Fig 1198 Fig 1199 Fig 1200 Fig. 1201 Fig 1202 Fig. 1203
December 1 1942 February 14, 1943 July 6 1943

Figs. 1198 1199 A 1½ year-old defect pseudarthrosis of the left radius. A gap of ½ cm. between the fragments. The distal fragment shows typical deviation towards the ulna and the dorsum with an angle of 20° in each direction. Central subluxation of the radius in the distal radio-ulnar joint. Gunshot injury in a 27 year-old man. Immediate debridement with removal of the splinters. The pseudarthrosis was freshened elsewhere and a 2 cm. section of the ulna was resected as in Figs I/1044–1047 Thereupon, medullary nailing of both bones with short nails.

Figs. 1200 1201 Same as Figs 1198 and 1199 10 weeks after the operation The fragments are in good apposition in both views. The subluxation at the distal radio-ulnar joint is corrected. Good callus formation.

Figs. 1202 1203 Same as Figs 1198–1201 immediately after extraction of the medullary nail and 7 months after operation. Bony union in good position The radial fragments show almost complete bony consolidation. The ulnar fracture line is still visible on the ulnar side. Rotation restricted one third, all other joints actively free.

during exposure of the fracture the operation must be terminated. Nailing must then be postponed until 3–4 months after closure of the wound, otherwise, inflammation may recur and sequestration may follow, as in Figs 1222–1227 It is best not to operate upon these cases at all

Freshening the fragments Only oblique or Z-shaped freshening is permissible, because transverse freshening may be followed by delayed union or pseudarthrosis (Figs 1212–1221)

Exposure of the medullary cavities If these are not patent after severance of the bone, they are opened with the awl or a gouge

The subsequent procedures are the same as in closed (see pages 339–342) and in compound forearm fractures (see pages 349–352), viz

Skin incision over ulna and radius

driving of the nail

coaptation and stabilization of the fragments with Lambotte clamp

X ray pictures,



Fig. 1204 Fig. 1205 Fig. 1206 Fig. 1207 Fig. 1208 Fig. 1209
March 9 1943 March 10 1943 May 4 1944

Figs. 1204 1205 A 10-months-old defect pseudarthrosis of the right radius. Gap of 3 cm. between fragments. The distal fragment shows the same typical deviation towards the ulna and dorsum as Figs. 1198 and 1199 with a radial angulation of 30° and a volar angulation of 15° Central subluxation of the radius at the distal radio-ulnar joint by about 20 mm. so that the entire defect in the length of the radius amounts to 5 cm. Marked decalcification of the radius and wrist joint. Comminuted gunshot fracture in a 30-year-old man the bone splinters were removed after 3 days.

Figs. 1206 1207 Same as Figs. 1204 and 1205 after operation performed *elsewhere* in which a 3 cm. section was at first removed from the ulna. The radial fragments were then exposed and freshened transversely The segment taken from the ulna was placed into the gap of the radius and the 3 fragments were then united with a 14 cm medullary nail. A 12 cm nail was used in the ulna. Good position of both bones. The central subluxation of the radius is corrected.

Figs. 1208, 1209 Same as Figs 1204–1207 after 14 months, and 3 months after removal of the medullary nails. The transplant from the ulna shows bony union with the distal fragment of the radius, but at the proximal juncture a pseudarthrosis developed. The radius is again bent with a radial angulation of 15° The fragments of the ulna show bony union. The implantation of a massive tibial graft into the radial defect, as in Figs 1228–1233 would have been a simpler and safer method, and the result more certain and more rapid.

rapid development
insertion of drains
skin suture and pressure bandage
removal of drains
exercises
removal of sutures
subsequent supervision
keeping a special record file
extraction of nails and
X *ray pictures at the conclusion of the treatment*

In Figs 1154–1157, too short a nail was used, therefore a supplementary plaster case had to be applied as in Figs 392–394 E, I/913–915 If the ulna had also been nailed the angulation of 10° could not have taken place

In the case of Figs 1160–1163 better stability could not have been obtained even with a longer nail. A supplementary plaster cast was applied from the knuckles to the shoulder in mid position of all joints.

Open Medullary Nailing of Old Fractures of the Ulna with Dislocation of the Head of the Radius

In fractures of the ulna with anterior or, less commonly, posterior dislocation of the radial head reduction is frequently unsuccessful with many surgeons, but we have always succeeded *in reducing fresh cases (Figs. 378–380 E I/864–874)* with the technique described on page I/500 and illustrated in Figs 381, 382 E, I/861–863

These fracture dislocations cannot be reduced conservatively if they are a few weeks old because the shortening can no longer be corrected by a single traction maneuver and because the joint is filled with scars and connective tissue Reduction can be accomplished only operatively In preparation for this, the shortening of the forearm must be corrected by continuous wire traction through the distal end of the radius A sling around the upper arm acts as counter traction The radial head thus recedes from the humerus to the level of its joint with the ulna. The anterior displacement, however persists The ulna straightens and the shortening disappears (Fig 1181)

After this has been achieved, the radial head is exposed under plexus anesthesia (see page I/101) from an incision on the dorsal surface A radial approach endangers the radial nerve which, after a dislocation, does not cross the anterior surface but the radial aspect of the bone This incision leads into the proximal radio-ulnar joint which is filled with the torn and scarred annular ligament. After its removal the lesser semilunar joint surface can be seen. The radial head can then easily be reduced by pressure from the volar surface The fracture of the ulna is then exposed from the dorsal surface The medullary nail is driven into the proximal fragment from the fractured end until it perforates the olecranon and bulges the skin, which is then incised The nail is next driven out further until it protrudes only 0.5–1 cm. from the fracture surface The two main fragments are then grasped with a Lambotte clamp and the nail is driven into the distal fragment. The wedge fragment which was left connected with the periosteum is then fastened with 2–3 wire loops (Figs. 1182 1183) After wound suture, a plaster cast is applied in mid position of all joints as in Figs 392–394 E I/913–915 This cast must be split immediately down to the skin along the ulnar or the radial side and not along the volar surface in order to retain the radial head in its reduced position.

Removal of the cast and sutures and application of a new cast After 8–10 days the first cast and the sutures are removed. A new cast is then applied which is not split.

X-ray pictures After the application of the new cast, as well as subsequently,

X-ray pictures must be taken every two weeks in both planes so as not to overlook a redislocation of the radial head as in Fig I/875

Exercises After the new cast has been applied, the fingers and the shoulder joint must be actively exercised through the full range

Removal of the plaster cast The cast is removed after 8 weeks (Figs 1184, 1185) By then the ulna is usually firmly united If not, another cast must be applied because this fracture shows a marked tendency to non union

Exercises Active exercises of the wrist, of forearm rotation and of the elbow are then begun Unfortunately, however a permanent restriction of rotation and of flexion and extension of the elbow is common as in Figs 1184 1185 To restore rotation, the head of the radius may be resected after bony union of the ulna Since a complete restoration of function is rare in old cases, all efforts must be directed at early recognition and reduction of this fracture dislocation

The subsequent steps are the same as in closed forearm fractures (see page 342), viz

Subsequent supervision
keeping a special record file
extraction of the nail and
X-ray pictures at the conclusion of the treatment

Rejection of Open Medullary Nailing in Pseudarthrosis of the Ulna with Dislocation of the Head of the Radius

Fractures of the ulna with dislocation of the head of the radius are frequently compound If the wedge fragment is removed during debridement or by suppuration a pseudarthrosis usually follows (Figs I/895–897) It may, however also follow closed fractures The joint capsule over the dislocated head of the radius is, as a rule ossified (Figs 1172–1179 and I/875 876 I/895–897) In dislocations of the radial head in juveniles (Figs I 877–880) and in fracture dislocations of adults in which the radial head is displaced not only forward but also laterally (Figs 1186 1187) ossification of the capsule does not occur and flexion and extension of the elbow may be free as shown in Figs I 879 880 If the radial head is merely displaced anteriorly and not radially as well the elbow can be flexed only to a right angle The strength and function are then greatly impaired In closed fractures of the ulna bony union may take place (Fig I/875)

If a pseudarthrosis of the ulna in this type of case is wired as in Figs I/895–897 or if a medullary nail is inserted as in Figs 1172–1179 and 1185–1197, bony union does usually not come about because the fragments of the ulna cannot be approximated completely since the radius acts as a strut. It is injudicious to resect the head of the radius as has frequently been recommended and done in the presence of a pseudarthrosis of the ulna because the arm is then entirely deprived of its support and because this measure will only rarely contribute to bony healing of the pseudarthrosis. Figures 1176 1177 and 1194, 1195 show that medullary nails may break as may supplementary wire sutures



Fig 1210 Fig 1211 Fig. 1212 Fig 1213 Fig. 1214 Fig 1215
January 21 1943 January 22 1943 May 26 1943

Figs. 1210 1211 A 13-months-old defect pseudarthrosis of the left radius. Gap of 1 cm. between the fragments. The distal fragment shows typical deviation towards the ulna and dorsum as in Figs. 1198, 1199 and 1204, 1205 Central dislocation at the distal radio-ulnar joint of 1 cm. showing that 2 cm. of the radius are lacking Complete decalcification of the entire radius with the cortex only as thin as paper Marked decalcification of the entire wrist, but good calcium content of the ulna. Suffered by a 24-year old man from gunshot injury The bone splinters were removed after 2 weeks.

Figs. 1212 1213 Same as Figs 1210 and 1211 after transverse freshening of both fragments of the radius *elsewhere* with removal of a 2 cm. section from the ulna and insertion of same into the defect of the radius and union of all fragments with 2 medullary nails. Good position in both views. The central dislocation of the radius is corrected.

Figs. 1214, 1215 Same as Figs 1212 and 1213 after 4 months. No trace of callus formation visible.

In the first edition I recommended for cases of pseudarthrosis of the ulna with dislocation of the radius correction of the shortening by skeletal traction through the distal end of the radius in the same manner as in old cases of this type followed by open reduction of the head of the radius. Since rotation remains markedly restricted or is even completely eliminated nevertheless (Figs 1184 1185) I am now advising against it It is best to leave the radial head untouched to expose the ulna through a dorsal approach and to saw into each fragment a step 4 cm long which only just exposes the medullary cavity leaving two-thirds of the circumference of the bone intact Both fragments are then joined by a bone graft with periosteum from the tibia The graft must be 8 cm longer than the gap in the ulna It is fastened to each fragment with 2 circumferential wire loops as in defect pseudarthrosis of the radius (Figs 1228–1233) A cast is applied for 12 weeks in mid-position of all joints as in Figs I 913–915 It must be split immediately and changed after 10 days



Fig 1216 Fig 1217 Fig 1218 Fig. 1219 Fig 1220 Fig 1221

February 24 1944 June 6, 1944 January 5 1945

Figs. 1216 1217 Same as Figs. 1212 and 1213 after 13 months. The nail in the ulna is broken

Figs. 1218 1219 Same as Figs. 1212 and 1213 immediately after removal of the medullary nails, 17 months after nailing and 30 months after injury There is now a pseudarthrosis of both bones. The fore arm dangles and is much weaker than before the operation. By implantation of a bone graft into the radius, bony union and good function could probably have been obtained in 3 months as in Figs. 1228–1233 and at that in a simpler and less dangerous way

Figs. 1220 1221 Same as Figs. 1218 and 1219 37 months after the injury and 3 months after the transplantation of an 8 cm. tibial graft into the radius and the ulna. Both bones united firmly

Further treatment is the same as in closed nailing of closed forearm fractures (see page 342)

A graft of sufficient length provides satisfactory stability in these cases and no medullary nail must be inserted as has frequently been recommended and done because it destroys the marrow and thus jeopardizes the taking of the graft The nail alone can never lead to a bony bridging of the gap as Figs 1172–1179 and 1186–1197 show On page I/506 from lack of adequate experience I recommended the use of a short medullary nail

There is no other old injury in which operative treatment with or without nailing has shown so many signal failures It is therefore most important to recognize and reduce this fracture dislocation early It will then heal in a few months as in Figs 381 382 E I/864–871 and I/872–874, and will not require treatment for years as in Figs 1186–1197 only to be eventually worse than before the operation

Closed Medullary Nailing of Pseudarthrosis of the Ulna

Transverse contact pseudarthrosis of the ulna as shown in Figs I/868–871 and I 970 971 causes no disability as a rule Therefore it requires no treatment If







Fig. 1222 Fig 1223 Fig 1224 Fig. 1225 Fig 1226 Fig 1227

January 22, 1943 January 23 1943 July 29 1943

Figs. 1222 1223 A 14-months-old defect pseudarthrosis of the left radius. Gap of 2 cm. between the fragments. Central subluxation of 1 cm. at the distal radio-ulnar joint, indicating a 3 cm. shortening of the radius. Only slight angulation because the fracture is located proximal from the middle. Marked decalcification of the radius, especially of the proximal fragment, while the ulna shows normal calcium content. Gunshot fracture in a 21 year-old man the splinters were removed 2 weeks after injury Free active motion of the fingers.

Figs. 1224 1225 Same as Figs. 1222 and 1223 after operation performed *elsewhere* only 4 weeks after closure of the sinus. First both radial fragments were freshened by the resection of a 1½ cm. piece from each Then a 5 cm section was removed from the ulna. A 10 cm. nail was driven into the radius. Since the nailing site was too close to the fracture the decalcified bone split and had to be held together with two circumferential wire loops. Another nail was driven into the ulna. The central subluxation persists. The bones are angulated.

Figs. 1226 1227 Same as Figs. 1222–1225 after 6 months. A violent inflammation followed the operation Sequestra separated from all four fragments. The forearm has become 7 cm shorter Both ulna and radius show a defect pseudarthrosis and the fingers are almost immobile.

pain appears however, closed medullary nailing may be taken into consideration since this measure is simple and without risk. To date, experience in this respect is lacking

Loose oblique non union causing discomfort can be cured by thorough freshening and bone suture In the first edition I still stated A medullary nail may be used additionally Guided by my experiences since then I now advise against it because the medullary nail does not stimulate callus formation but retards it

Intentional Production of Pseudarthrosis of the Ulna for the Restoration of Rotation of the Forearm

Forearm rotation is impossible if an ankylosis develops in the distal radio-ulnar joint following compound fractures or gunshot fractures with infection, or if a



Fig. 1228 Fig 1229 Fig 1230 Fig. 1231 Fig 1232 Fig. 1233
August 31 1943 September 2 1943 January 2, 1945

Figs. 1228, 1229 A 2 year-old defect pseudarthrosis of the left radius. A gap of 4½ cm. between the fragments. The distal fragment deviates towards the ulna and is dislocated centrally by 2½ cm. indicating a total shortening of 7 cm. Gunshot fracture in a 24-year-old man the splinters were removed. Marked decalcification of the radial fragments and of the wrist. The sinuses closed after one year Nine months later the extensive scar was excised and an 8 x 12 cm. skin flap was transplanted from the abdomen

Figs. 1230 1231 Same as Figs. 1228 and 1229 after implantation of a tibial graft with periosteum, 14 cm. long and 1½ cm. thick. This operation was performed 3 months after the skin grafting and one year after closure of the sinuses.

Figs. 1232 1233 Same as Figs 1230 and 1231 after 16 months. The bone graft healed in without wound complications. It is firmly united with both fragments. The prominent distal end of the ulna was removed.

bridge callus has formed. This condition constitutes a great handicap for many occupations and can be corrected by transversely resecting a 1–1.5 cm long piece of bone with periosteum from the ulna above the fusion of the 2 bones Post-operatively a dorsal splint is applied for 2 weeks. Active exercises are then started within the limits of pain This achieves a considerable or even complete restoration of rotatory function (see page I/599 and Figs 1242–1247)

Maintenance of Pseudarthrosis of the Ulna in Bridge Callus

It occasionally happens that a defect pseudarthrosis (Figs 1248–1251) develops from sequestration or debridement proximal to a bridge callus This condition must not be corrected because rotatory motions would be lost. I wish to point this out because many such cases were referred to us for bone grafting or medullary



Fig 1234 Fig. 1235 Fig. 1236 Fig 1237

May 19 1939 February 17 1940

Figs. 1234 1235 Comminution of the left ulna for a distance of 6 cm. Shell fragment injury in a 23-year old man The wound was immediately excised *elsewhere*. All splinters were removed and both fragments sawed off transversely producing an 8 cm. defect.

Figs. 1236, 1237 Same as Figs. 1234 and 1235 after 9 months. Both fracture stumps are rounded off.

nailing and because I have seen that among those in whom the pseudarthrosis was corrected the function of the arm was much worse than before

Rejection of Open Medullary Nailing in Pseudarthrosis of the Radius

Pseudarthrosis of the radius alone is usually associated with a more or less pronounced subluxation at the distal radio ulnar joint because of shortening In pseudarthrosis of the distal third the proximal end of the distal fragment usually deviates toward the ulnar and posterior aspect (Figs 1198, 1199) The hand deviates towards the radial side is flexed at the wrist and is markedly pronated Supination is impossible Pseudarthrosis in the proximal third is usually not associated with angulations worth mentioning (Figs 1222 1223)

Since the power and function of the hand are greatly impaired by this condition we must try to correct it

In the case of Figs 1198–1203 operated elsewhere for a pseudarthrosis of the radius, the initial result appeared good in the first edition I therefore recommended a transverse resection of the ulna freshening of the radius and medullary nailing of both bones I now advise strongly against it because a follow up revealed that pseudarthrosis recurred in the radius

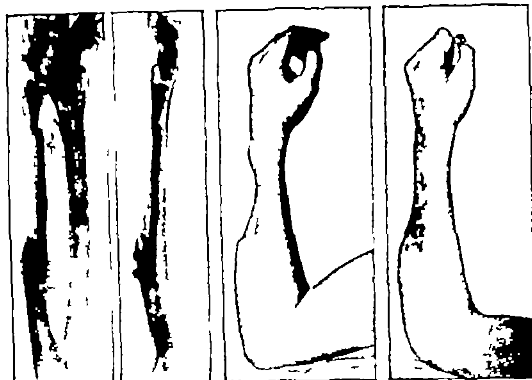


Fig 1238 Fig. 1239 Fig 1240 Fig. 1241
May 22 1940 February 26, 1940 June 4 1940

Figs. 1238 1239 Same as Figs. 1236 and 1237 3 months after the implantation of a 15 cm. tibial graft with periosteum. It was implanted into the cancellous bone of the distal fragment and at the proximal fragment it was fastened with 2 circumferential wire sutures which were first carried through drillholes and then wound around 1½ times. Bony union of all three fragments.

Fig 1240 Photograph to Fig. 1236 The retracted scar indicates plainly the defect in the ulna.

Fig. 1241 Photograph to Fig. 1238. The shape of the forearm again approaches the normal Good fist closure.

We now treat these cases as before by step-down shortening of the ulna and oblique freshening of the radius as in Figs 422–428 E I/1044–1050, or preferably by the transplantation of a long massive periosteal bone graft from the tibia

Rejection of Open Medullary Nailing in Defect Pseudarthrosis of the Radius

If the defect on the radius amounts to more than 3 cm., the ulna must not be shortened in the manner shown in Figs I/1051–1058 because the forearm would become too short and its strength greatly impaired

In exceptional cases of this type, one may correct the upward dislocation of the distal fragment at the distal radio-ulnar joint by continuous wire traction as in Fig 1181 if the fingers show good motion Traction, however, must not be used if extensive soft tissue scars are present or if the motion of the fingers is restricted Extensive scars adherent to the bone must be excised and covered with a skin graft from the abdomen Several months later both fragments are freshened for a distance of 4 cm A massive periosteal bone graft of adequate length and strength is then fastened to each fragment with 2–3 circumferential wire loops (Figs 1228–1233) A cast is then worn for 12 weeks The operation may not be performed






Fig. 1242 Fig. 1243 Fig. 1244 Fig. 1245

February 28, 1940 April 16, 1940

Figs. 1242 1243 Ankylosis of the wrist joint 6 months after injury The lunate, the triquetrum and the distal ends of the radius and ulna are comminuted and synostosed Pro-supination entirely lost. Rifle shot injury in a 23-year-old man.

Figs. 1244 1245 Same as Figs. 1242 and 1243 after 6 weeks. A 1 cm. section with its periosteum was removed from the ulna near the distal end. No new bone was produced in this gap. An X-ray picture 4 years later showed the same findings.

until 6 months after the closure of all sinuses It is even better to wait until the calcium content of the bones and the circulation in the soft tissues have returned close to normal.

Not until after the graft has taken firmly, may the ulna be shortened by Z-shaped freshening as in Figs 422–428 E I/1044–1050) My present experiences cause me to advise against the use of a medullary nail in such cases, although I did recommend it in my first edition A simpler and better procedure than the shortening of the ulna in its shaft is the resection of the prominent distal end of the ulna (Figs 1232 1233)

Implantation of a section of the ulna into the radius I had occasion to see a considerable number of patients who had been treated elsewhere by this operation In none did bony union develop The best result was obtained in the case of Figs 1204–1209 Bony union occurred on the ulna and between the transplant and the distal fragment of the radius but the proximal fragment did not unite in spite of 11 months of supplementary immobilization in a plaster cast.

In the case of Figs 1210–1221 a pseudarthrosis of both bones resulted even though a supplementary plaster cast had been used for 13 months The forearm was flail as shown in Fig I 1036 Not until tibial grafts were used did both bones unite

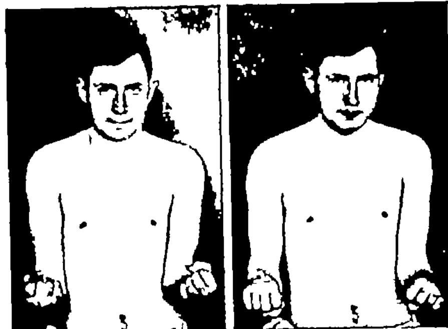


Fig 1246 Fig 1247

April 16, 1940

Figs. 1246, 1247 Photographs to Figs 1244 and 1245 6 weeks after resection of the ulna. A considerable degree of forearm rotation which was completely lacking before the operation has been regained. According to a written communication from the patient dated June 21 1944 the rotation has become normal

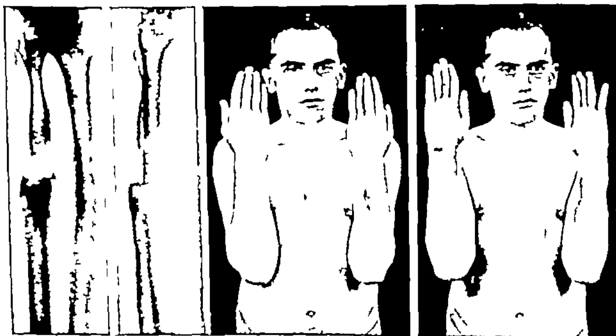


Fig 1248 Fig 1249 Fig 1250 Fig. 1251

February 14 1944 February 14 1944

Figs. 1248, 1249 A 2 year-old defect pseudarthrosis of the left ulna in the distal third, with partial bridge callus. Gunshot injury in a 23-year-old man.

Figs 1250 1251 Photographs to Figs. 1248 and 1249 There is almost normal rotation of the forearm because of the pseudarthrosis of the ulna which developed from removal of splinters proximal to the bridge callus. If the bone defect were corrected with a graft the rotation would be greatly restricted and the function of the arm worse.



Fig 1252



Fig 1253

October 30 1942

Figs. 1252, 1253 *Compound* **fractures of the 2nd–4th right metacarpals. The distal fragments of the second and third metacarpal show complete lateral displacement towards the dorsal and ulnar side with shortening. Caused by a heavy piece of iron which fell onto the hand of this 51 year-old draftsman. Immediate wound excision and introduction of stainless wires into the fragments.**

If infection supervenes as in the case of Figs 1222–1227, the arm and hand are very seriously damaged Before the operation the fingers were actively free, where as afterwards they were almost immobile

In view of these experiences, medullary nailing for defect pseudarthrosis of the radius must be rejected in particular the transplantation of a section of the ulna because this frequently results in a pseudarthrosis of both bones

Rejection of Open Medullary Nailing in Pseudarthrosis of Both Forearm Bones

In pseudarthrosis of both bones of the forearm the strength and usefulness of the hand are seriously impaired We therefore endeavor to correct this disability, provided the general and local conditions permit

Causes of forearm pseudarthrosis With other long bones a pseudarthrosis is as a rule an avoidable result of the treatment method on the forearm however, it is frequently caused by primary loss of bone tissue

The most common cause however is the removal of fragments during the de bridement of compound fractures and premature massage and passive motion in closed and compound fractures

Excessive continuous traction is rarely used in forearm fractures and is therefore a rare cause of non union but if wire traction is used for forearm fractures pseudar throsis is the rule Consequently it must be rejected

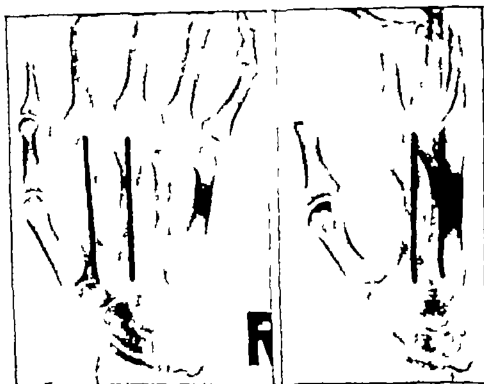


Fig. 1254 Fig 1255

February 20, 1943

Figs. 1254 1255 Same as Figs. 1252 and 1253 after 12 weeks. Bony union in good position. In the future we will provide such compound fractures not with medullary wires, but merely with a wire suture to the second metacarpal as in Fig. I/1365 since in case of infection the entire medullary canal might become involved.

In the first edition I recommended for the treatment of pseudarthrosis of both forearm bones, nailing of both bones after transverse or oblique freshening of the fragments. From my present experiences (Figs 1166–1171), I must warn against it

In the first edition I also wrote that medullary nailing would have been simpler than wire suture or bone grafting in the cases shown in Figs 182–185 186–195 E, I/265–268 I 269–276 I 1051–1058 and I/1059–1062 Now I must add It is much more uncertain hazardous and time-consuming

Prohibition of medullary nailing in pseudarthrosis of the forearm In view of the poor results following medullary nailing in pseudarthrosis of both forearm bones as well as in that of the ulna and radius alone I have prohibited it within my jurisdiction

FRACTURES OF THE METACARPAL BONES

Rejection of Open Medullary Nailing in Fractures of the Metacarpal Bones

In transverse fractures of several metacarpal bones with displacement by full shaft thickness or more and with shortening it is at times extremely difficult to retain good position after reduction This is particularly true of compound fractures in which the cast must be fenestrated because of wounds. We therefore provide such fractures with wire sutures (Figs I/1365 a and b) In one case Güttner

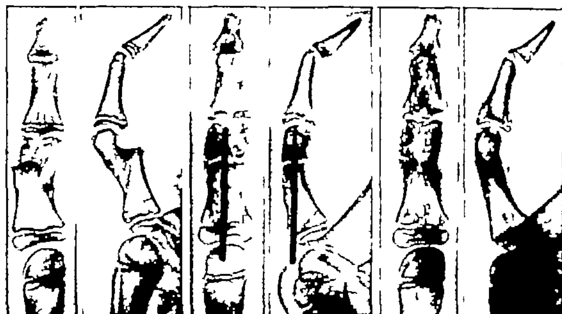


Fig. 1256 Fig. 1257 Fig. 1258 Fig. 1259 Fig. 1260 Fig. 1261

July 10, 1942 November 11 1942 January 13 1943

Figs. 1256, 1257 Mal-united fracture of the proximal phalanx of the right index finger with dorsal angulation of 20° and ulnar angulation of 10° In a 12 year-old boy who suffered a compound fracture when a heavy cover fell on his finger

Figs. 1258, 1259 Same as Figs. 1256 and 1257 4 weeks after osteotomy and uniting the fragments with a stainless steel wire. Good position in both views.

Figs. 1260 1261 Same as Figs. 1258 and 1259 after removal of the wire and 3 months after the operation. Bony union in good position.

introduced stainless wires from the proximal end The result was good (Figs. 1252–1255) In spite of this we do not practice the use of the medullary wire in fresh compound fractures of the metacarpal bones, since in case of infection the entire medullary canal would be involved, whereas without it merely the fracture stumps would be affected.

FRACTURES OF THE PHALANGES

Open Medullary Nailing of Fractures of the Phalanges

In fresh fractures of the finger phalanges good position can usually be retained with plaster and wire splints (Figs 552–555 E I/1399–1402) In old fractures, this is frequently very difficult after operative correction of the mal-position (Figs. 572–573 E I 1462 1463) In such cases the lateral displacement and angulation can be prevented by the insertion of a longitudinal wire (Figs 1256–1261) In addition a dorsal plaster splint and a wire splint must be applied (see pages I/713–715 and Figs. 541–543 556–559 E I/1384–1395) It must be emphasized, however that the risk of infection is much greater than with the old methods

For fractures of the middle and terminal phalanges, medullary nailing cannot be considered because the bones are too short and because they have no tendency to become redisplaced.

Open medullary nailing should be rejected for the treatment of fresh compound fractures of any of the phalanges.

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INDEX